COMBUSTION

SEP 1 1943

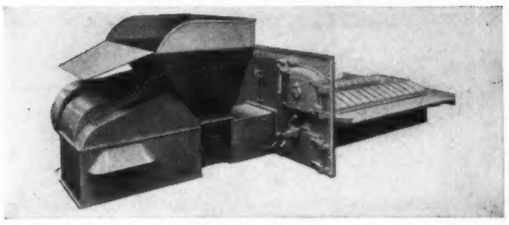
DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

AUGUST, 1943

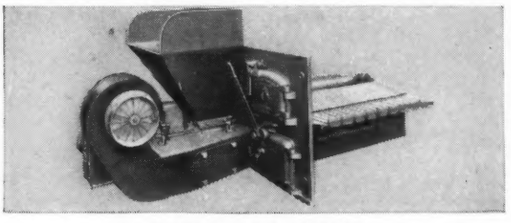
Front corner of a water-cooled furnace viewed from under the rear arch, unretouched, and showing only part of the grate of a giant 24 x 23 ft traveling grate stoker

Topping Program at SHERMAN CREEK ▸

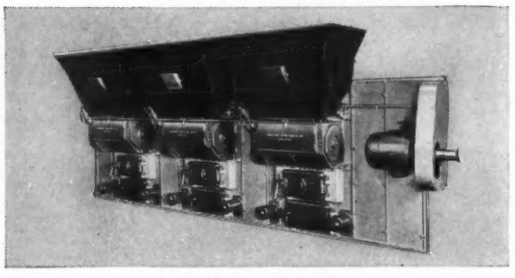
CORROSION by Liquids ▸



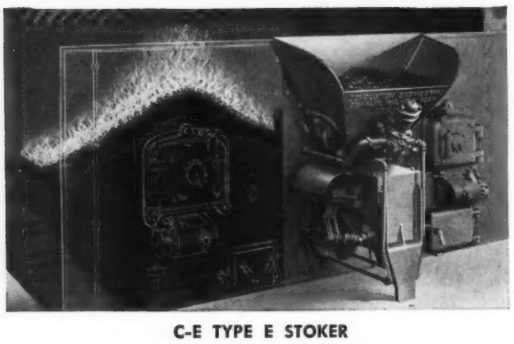
C-E SKELLY STOKER



C-E LOW RAM STOKER

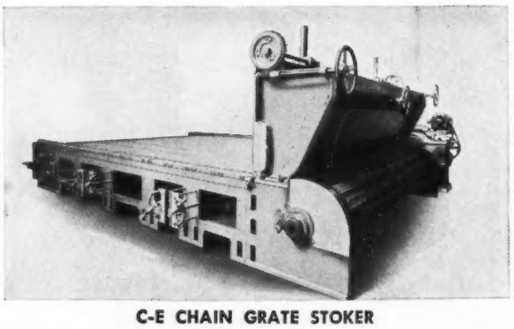


C-E SPREADER STOKER



C-E TYPE E STOKER

C-E TRAVELING GRATE STOKER



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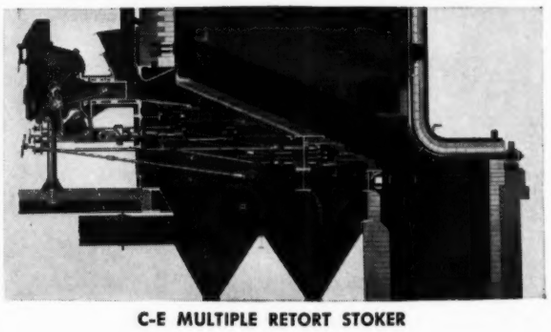

C-E MULTIPLE RETORT STOKER

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME FIFTEEN NUMBER TWO

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FOR AUGUST 1943

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EDITORIAL

Patent System Vindicated

In view of the numerous accusations that have been directed against our patent system and charges by responsible individuals of the Government that certain abuses had hindered the war effort, it is gratifying to read the report of the National Patent Planning Commission which was appointed by the President some months ago to review the whole patent situation. The standing of the personnel of this commission gives weight to its findings.

To begin with, the Commission, after exhaustive study, came to the conclusion that the American Patent System is fundamentally the best in the world and that, in no instances, had it been responsible for serious interference with prosecution of the war. However, it did find that, without nullifying any of the basic principles, certain adjustments in the system are desirable in order to meet existing conditions. These it incorporated in a number of recommendations for which legislation will be requested. Among these suggestions are the following:

That all existing and future agreements, regardless of the citizenship of the parties concerned, involving price, quantity of production, geographical or field of use, be recorded and available to public scrutiny.

That any person be accorded the opportunity to challenge the validity of a patent within six months after its grant, but that failure to do so shall not prejudice the rights of an individual in a subsequent infringement suit.

That, because of the ever-widening gulf between Patent Office decisions and those of the courts, there be a greater uniformity in the granting and treatment of patents, and that a single court of patent appeals be established.

That no patent monopoly should endure for more than twenty years from the date of the original filing in the Patent Office, in order to avoid deliberate delays aimed at keeping a patent pending for an indefinite period. A further recommendation dealt with simplification in appellate procedure.

Despite much agitation to the contrary, the Commission concluded that it would not be in the public interest to have a general system of compulsory licensing, except in special cases where, in the opinion of the court, this might be necessary to national defense or be required by public health or public safety.

It is believed that these findings will be accorded general acceptance and serve to allay the many loose accusations that have been current against our patent system.

With the amendments suggested it is expected that our Patent System will continue to encourage and reward American inventors in the invention and development of new products and processes and protect the individual in the formative period of a new enterprise, as it has done for the last hundred and fifty years.

Presumably, in due time, Congress will legislate on the constructive suggestions offered.

Convention Curtailment

Joseph B. Eastman, Director of the Office of Defense Transportation, has renewed his request for the cancellation, wherever possible, of conventions and similar group meetings because of the present heavy passenger traffic superimposed on extensive troop movements and furlough travel of service men—a situation that is becoming increasingly acute.

Although many organizations responded patriotically to his first appeal, made last spring, others ignored it and went ahead with their prearranged plans. Some of these meetings in non-technical fields had little or no bearing on the war effort and some were in the nature of annual gatherings in which social features predominated.

On the other hand, in the engineering field many programs were specifically directed toward the solution of problems incurred by the war, and as such were justified. But even in this field, the present is not the time for the usual coverage of all branches, and program committees would do well to confine their efforts to the solicitation only of papers related to war problems, to the end that attendance may be held down to those who would benefit most by attending. This applies particularly to panel discussions which afford an opportunity for the informal exchange of ideas and experience.

One suggested means of cutting down on such travel is that wider resort be made to the presentation of the same paper before various local meetings. Obviously, this would largely preclude personal presentation by the author at more than a very few meetings, but this disadvantage might be offset by a larger aggregate audience and perhaps more extensive discussion.

Mr. Eastman states further that he is fully aware that the constitutions and bylaws of many organizations stipulate the holding of annual meetings and that cancellations may raise questions as to the tenures of officers. However, he reminds us that war time calls for emergency procedures which can usually be adopted when there is a will to cooperate. In some cases, these have taken the form of skeleton business meetings in the place of annual conventions.

With the fall convention season ahead and no let-up in demands upon the railroads in prospect, it is to be hoped that Mr. Eastman's second warning will be heeded lest restrictive measures become necessary. Such measures would likely be very unpopular.

Topping Program at SHERMAN CREEK Part I—Steam Generation

By R. T. ROBERTS

Assistant Division Engineer,
Consolidated Edison Company of New York, Inc.

A description of the steam-generating equipment supplying a million pounds of steam per hour at 1600 psi, 950 F to a 50,000-kw topping turbine-generator which, in turn, exhausts to 49,000 kw of existing low-pressure capacity. This is the first of four such units planned for ultimate installation in this station. A second article, to appear later, will describe the turbine and its auxiliaries, also the station heat balance.

WHEN the No. 90 boiler and turbine at Sherman Creek went into operation last April, the Consolidated Edison Company of New York, Inc. completed the first step in a program of modernization of this station. The ultimate program calls for four high-pressure boilers, each to serve one 50,000-kw turbine, the exhaust steam from each to generate one-quarter of the station's low-pressure capacity.

The boiler is designed to generate 1,000,000 lb of steam per hour at 1600 psi and 950 F at the turbine throttle. In the selection of these conditions, many studies comparing the economy of various schemes were made.

The planning started with consideration of the ultimate installation, together with physical limitations of the site. The boiler room, which is bounded by three streets, is practically square, which dictated a symmetrical arrangement of four boilers for maximum space utilization. The amount of low-pressure capacity for ultimate consideration is 196,000 kw. This capacity could not be accommodated by two topping turbines since the capacity of each would have exceeded existing manufacturing limitations. As a consequence, four units were decided upon, the first of which occupies one-fourth of the available space and will supply sufficient steam to meet one-fourth the ultimate requirements, or 49,000 kw. With this basic assumption the steam to be exhausted by the high-pressure turbine was established, the capacity depending on initial steam conditions and the cycle arrangement. The higher the initial pressure and temperature the greater was the capacity of the topping unit for a given exhaust pressure.

In choosing the initial steam conditions and cycles for study, a number of inter-related factors had to be considered. The maximum safe temperature for carbon molybdenum steel established the initial temperature limit at 950 F. Preliminary studies indicated that the pressure should be made as high as was consistent with adequate steam temperature for the low-pressure turbines, with due consideration as to cost of the boiler and other pressure parts.

With a fixed initial temperature to the topping turbine, increasing initial pressure reduces the 200-lb exhaust temperature, and vice versa. It was desired to maintain superheat about 100 deg F or above in the 200-lb steam to the low-pressure turbines, since maintenance becomes excessive due to water erosion in the lower stages when sufficient superheat is not maintained. To meet these low-pressure steam conditions without the expense of reheat, 1600 lb appeared to be the upper limit to initial pressure with 950 F total steam temperature.

With limitations on X-ray inspection of drum welding at the time this study was made, the pressure limit for

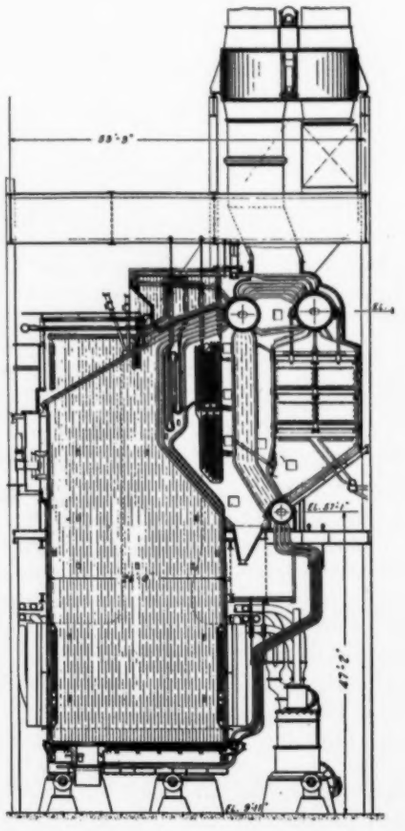


Fig. 1—Cross-section through steam-generating unit

welded drums of the thickness required in this case was approximately 1700 lb, or about 1600 lb at the throttle, deducting superheater pressure loss. The top pressure for welded drums with the top temperatures for carbon molybdenum steel resulted in an exhaust temperature from the topping turbine appropriate for the existing low-pressure units. This fact dictated schemes "B_1" and "B_2."

Scheme "A" in the following table was chosen as the basis of comparison since it represents conventional topping practice. The cost of additional capacity made available by higher initial steam conditions is shown in the tabulation.

Higher pressures with reheat were considered, one typical case of which is shown in "D_1" but proved unattractive since boiler and piping costs increase substantially with increased pressure and reheat. At the time of making this study, prices of reheat boiler equipment and necessary piping were such as to penalize the cycle. Since the low-pressure turbines are built for a maximum temperature of about 600 F the economy of reheat is limited, while the major portion of the reheat investment would be required.

The following shows four of the numerous schemes used in the preliminary study based on a constant low-pressure turbine-generator capacity of 49,000 kw.

Scheme	A	B_1	B_2	D_1
Throttle, steam, high-pressure unit				
Pressure, lb per psi G	1,250	1,600	1,600	2,200
Temperature, F	925	950	950	900
Flow, lb per hr	765,000	839,000	885,000	888,000
Reheat temperature, F	...	...	...	900
Final feedwater temperature, F	386	446	488	533
Station heat rate, Btu per net kwhr	11,415	10,965	10,900	10,650
Net added capacity, kw	37,260	43,865	44,930	48,380
Capacity gain over A, kw	...	6,605	7,670	11,120
Cost per added kw over A (value of basic capacity $100/kw)	...	$26.80	$40.60	$108.00
Cost per added kw over B_1 (value of basic capacity $100/kw)	...	...	$126.20	$226.50
Cost per added kw over B_2 (value of basic capacity $100/kw)	...	...	...	$258.00

Fig. 2—Bifurcated-tube water walls

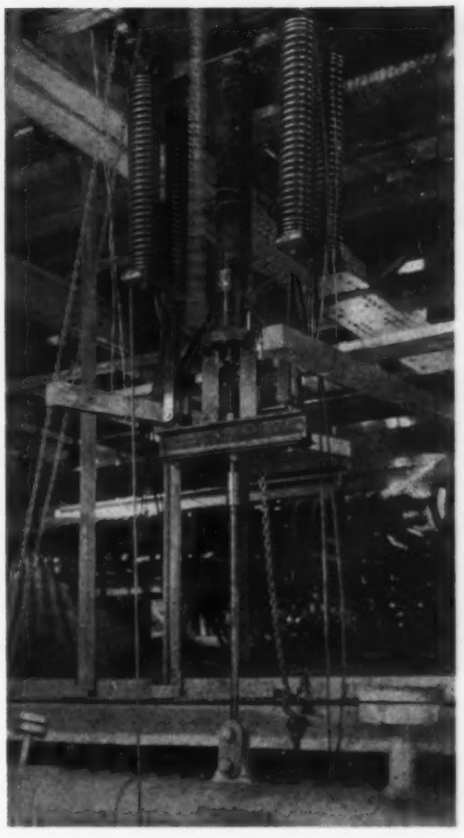


Fig. 3—Spring hangers supporting superheater header

From the above, it can be seen that Scheme "B_1" having the lower basic added cost would be the most economical and therefore establishes the initial steam pressure of 1600 lb at the temperature of 950 F.

Steam-Generating Unit

The steam-generating unit selected (Fig. 1) is of the three-drum bent-tube type designed for 1800 lb working pressure and tangentially fired with pulverized coal. It has a slagging-bottom furnace and was furnished, delivered and erected by Combustion Engineering Company, Inc. The space occupied was originally intended for twelve 650-hp, 200-lb boilers of which only the six first-floor boilers were installed. Six additional first-floor boilers were removed to accommodate the turbine installation. This area provides enough space for the next topping turbine. The surfaces are disposed as follows.

Boiler	12,906 sq ft
Water walls	10,995 sq ft
Superheater	30,712 sq ft
Economizer	34,020 sq ft
Air preheaters (each)	142,600 sq ft

The upper front drum is 54 in. diameter with $5^{3}/_{32}$-in. and $4^{11}/_{16}$-in. plate thickness; the upper rear drum is 60-in. diameter with $5^{3}/_{16}$-in. and $4^{27}/_{32}$-in. plate thickness;

Fig. 4—Precipitator hoppers and pneumatic ash-conveyor system

while the lower drum is 36-in. diameter and has a thickness of $3^{13}/_{32}$ in. All drums are fusion welded.

The 60-in. diameter drum is equipped with a steam washer and drier. A feedwater pipe enters the drum and connects to a perforated feedwater trough over which is located a steam baffle of alternate hoods and spaces. Steam enters the hoods, passes through perforations in the hoods which are below the water line and emerges into the steam spaces. By this contact, the concentration of solids in the moisture in the steam is decreased. The steam then leaves the drum through rod-type driers.

The furnace is completely water-cooled and is formed by 3-in. O.D. bifurcated tubes (Fig. 2) on $3^1/_8$-in. centers backed by special rolled-steel sections to close the space between the tubes, steel plate, 2 in. of high-temperature block insulation, a 3-in. rockwool blanket and steel casing. Roof and bottom tubes are finned and the rear wall tubes are bifurcated at the header end but not at the drum end. The furnace volume is 54,400 cu ft and the calculated heat liberation at 1,000,000 lb output is 22,100 Btu per cu ft.

The Elesco superheater is of the pendant type and consists of two sections located behind the rear wall riser tubes and ahead of the boiler section. It is designed to raise the temperature of the steam to 955 F, plus or minus 10 deg, at a pressure of 1625 psi at the superheater outlet with the furnace fired with pulverized coal and with excess air corresponding to 14 per cent CO_2 at the economizer outlet. The steam outlet temperature is controlled by a damper at the economizer inlet operated by a power cylinder and controlled by a thermostat in the superheated steam header.

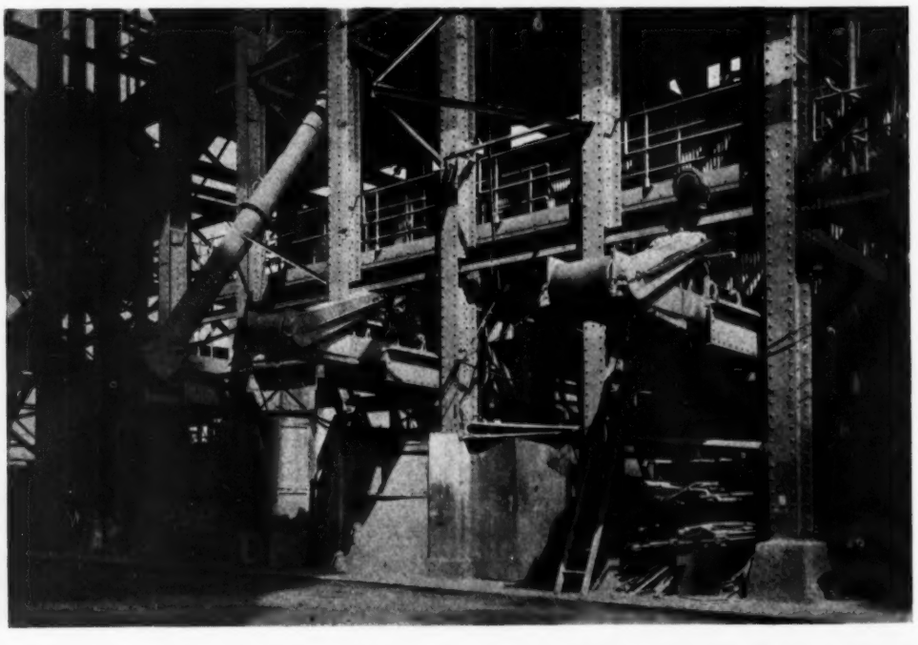


Fig. 5—Reversible conveyor for ash from ash conditioners (land side)

Tubing in the superheater elements nearest the furnace is of chrome-molybdenum alloy seamless low-carbon hot-finished steel, and that in the rear section near the economizer is of carbon-molybdenum seamless low-carbon hot-finished steel. Provisions for sampling saturated and superheated steam are included.

The superheated steam outlet header is equipped with a power-controlled safety valve in addition to the Code requirements in order to control more accurately the blowing pressure and blow-back.

Fig. 3 shows the method of suspension of the superheater header.

Because of the fact that the boiler and turbine are laid out to operate as a unit, no non-return valve was placed between the superheated steam outlet header and the turbine. The Boiler Code thus covered the fabrication of the main steam piping up to the turbine throttle.

A split-type Elesco economizer is provided, having 2-in. diameter finned tubes 46 wide and 16 high for each half on 8-in. vertical spacing and 3-in. horizontal spacing. The gas pass is up through the economizer with parallel water flow. The tubes are hot-finished low-carbon seamless steel and the entire economizer is designed for the most convenient access.

Two Ljungstrom regenerative-type air preheaters are located in the gas stream after the economizers. They have 72-in. deep elements and are equipped for water washing the surfaces. Recirculating fans are also provided to draw hot air from the heater outlets and discharge to the heater inlets, the object being to raise the heater plate temperatures during periods of low load so that corrosion and fouling are diminished.

Dust and Fly Ash Recovery System

In order to maintain as clear a stack as possible, a Cottrell precipitator, capable of removing 95 per cent of the entrained solid material in the flue gas was installed. This precipitator is of the horizontal-flow, steel-plate electrode type, and is designed for a flow of 460,000 cfm at 340 F. It is the largest of its type to date.

Dust and fly ash is handled pneumatically (see Fig. 4) from the precipitator hoppers and points of lodgment in the boiler and duct-work and deposited in ash pockets on the dock. The ash-handling machinery is located in a room above the ash pockets and is in duplicate. The vacuum pumps are remotely controlled through push buttons from a control board located at the boiler. The system is arranged to operate either through automatic or hand control; the change from one loading point to another in the system being controlled through sequence. From the ash pockets, fly ash is discharged through two rotary conditioners to render it dustless. These conditioners are installed in parallel and discharge to reversing conveyors so that the ash can be loaded either to barges or trucks (see Fig. 5).

Slag-Handling Mechanism

A novel feature of the installation is the slag-handling mechanism. As slag flows from the bottom of the furnace, it falls through a water spray and disintegrates into particles about the size of rice. A leaf damper directs the slag to one of two pits, each having an inclined bottom. Mounted over each pit is a reciprocating slag rake, the motion of which is alternately backward (upward) and forward (downward). On the forward or downward motion, the rake is lifted above the slag and moved toward the lowest point of the pit. As the forward motion ceases, the rake is lowered into the slag and the backward motion starts. Slag is raked up the incline for a distance during this backward motion. The rake then disengages and starts on the forward motion and as this is repeated, the slag is brought to the top of the incline and drops over the apron into a car, as shown in Fig. 6. The car is then dumped into the station skip hoist for hoisting to the ash pockets. The ash and slag handling system has been designed to make this work as clean and convenient as possible.

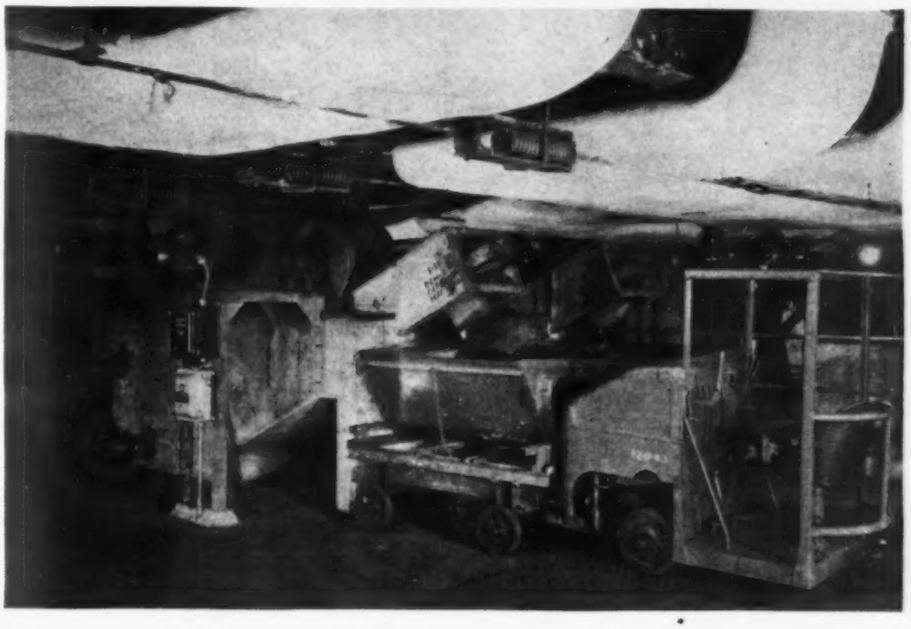


Fig. 6—View of reciprocating slag rake discharging into cars

Flues between the boiler and air preheater, the air preheater and precipitator, and the ducts between the forced-draft fan and the air preheater are worthy of mention. They are of streamlined design to reduce losses to a minimum, and are without stiffeners (see Fig. 7).

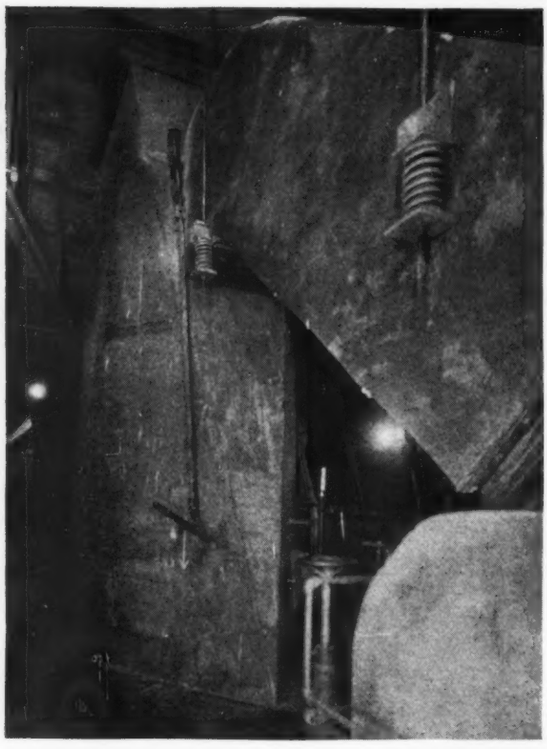


Fig. 7—Air duct from forced-draft fan to air preheater, with recirculating fan discharge at upper right

Forced- and Induced-Draft Fans

The two induced-draft fans are of the B. F. Sturtevant "Turbovane" type designed for handling 247,000 cfm at 13-in. static pressure, and are driven by a single Worthington turbine located between them (see Fig. 8). The drive is a turbine gear set having a double-ended driving shaft. The reduction gear consists of a double helical gear and pinion having a ratio of 217 to 40. The turbine has a normal rating of 1000 hp at 4930 rpm with 185-psi 485 F steam to the throttle, but will develop 1410 hp at 5500 rpm under the same steam conditions. It is non-condensing and has seven impulse stages.

The forced-draft fans are American Blower Corporation type, each designed for 147,000 cfm at 15-in. static. Like the induced draft fans, they are driven by a single turbine through a gear-set consisting of a double herring-bone gear and pinion with a ratio of 214 to 41. The turbine, of General Electric design, has a normal rating of 574 hp at 5324 rpm with 185 psi, 485 F steam to the throttle, but will develop 878 hp at 6134 rpm. It exhausts at 3 lb psi gage. Both the induced- and forced-draft turbines have separately driven oil pumps.

The furnace, boiler, superheater, economizer and air preheaters are provided with Diamond soot blowers. Motor-driven telescopic blowers are placed in the side walls to clean the superheater and Model IH blowers are located in the roof to clean the superheater inlet. These blowers are cooled by air taken from the forced-draft fan discharge. To eliminate individual piping and provide clearer working space and better conditions, this air is piped to a plenum chamber formed by the boiler roof steel so that a certain amount of cooling of the floor where the operator stands is accomplished before the air escapes through the soot blowers into the furnace. This arrangement is indicated in Fig. 9.

Mills and Burners

Three Raymond bowl-type mills (Fig. 10) are provided, each designed to pulverize 32,700 lb per hr based on coal having a grindability of 55 Hardgrove scale with 8 per cent moisture and grinding to a fineness of 70 per cent through 200 mesh.

The boiler is tangentially fired by twelve burners, three located in each corner. One mill serves the same burner in each corner so that with one mill in operation all four top, middle or bottom burners would be in service. The burners are arranged so that the bottom burner in each corner is stationary and the top two burners adjustable in the vertical direction (see Fig. 11). Provision for four auxiliary burners in the upper front wall was made in case superheat was low at low load.

Gas ignition torches are placed between each pair of

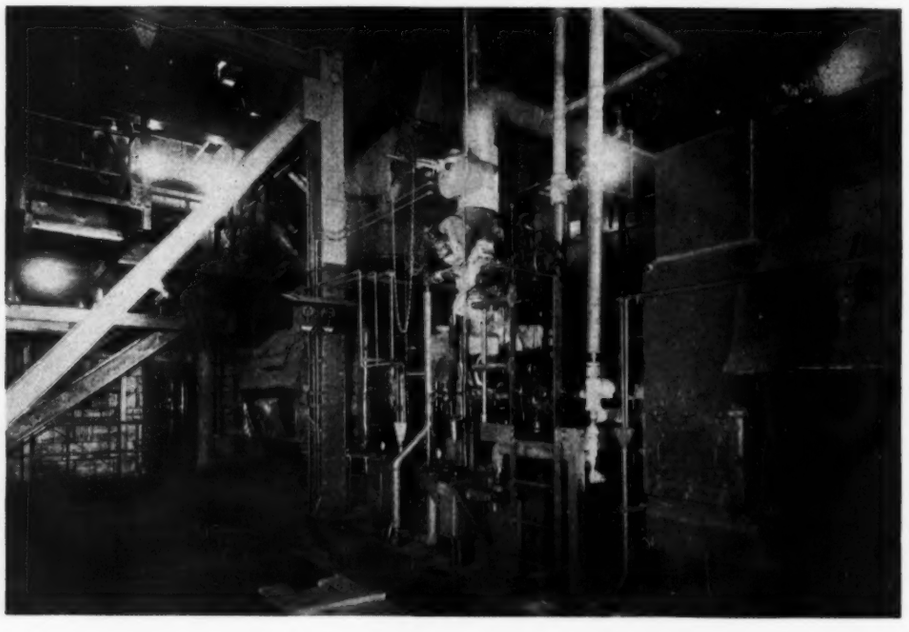


Fig. 8—Turbine-driven induced-draft fans

burners, two to a corner. These ignition torches are automatically controlled from the control board, with a separate control for each tier of torches. Solenoid-operated gas valves control gas flow so that no flow can occur unless the igniters are energized.

The burners are operated by an air cylinder located below the burner box which is controlled by a hand sender on the boiler-control board. Elevation is also indicated at the board by a dial. In addition, each burner is equipped with a tilting adjustment and indication at the burner which shows the angular movement of the burner with full stroke of the cylinder. The entire ignition and burner system has been designed to be easily and safely operated with a minimum of labor.

Coal-Conveyor System

Preparatory to installation of the steam-generating unit a belt conveyor system was installed in order to remove the coal cable road over which fuel was originally handled in the station. A system of belt conveyors serving the two towers on the dock was installed above the bunkers in the station. Below the bunkers serving this installation a run-around Redler conveyor was installed in order that the coal which would not flow by gravity to the mills could be moved. In order to simplify the control of this and future boilers, the entire control is located on the 72 ft 1 in. elevation. On this elevation are assembled the control benchboard and panel, feed-pump control and the sight-gage system from gage glasses to the control board. Boiler-feed pumps, mill feeders and chemical feed tanks are also located at this elevation.

Boiler Control Board

The combustion control was furnished by Republic Flow Meters Company and is arranged to regulate air flow, furnace draft and coal feed to maintain steam pressure. The control also functions to control the steam to the fan turbines.

Bailey Meter Company three-element control (water flow, steam flow and water level) is provided to vary the speed of the turbine-driven feed pumps as required by feedwater demands of the boiler. The water level is brought visually to the control board by a system of mirrors.

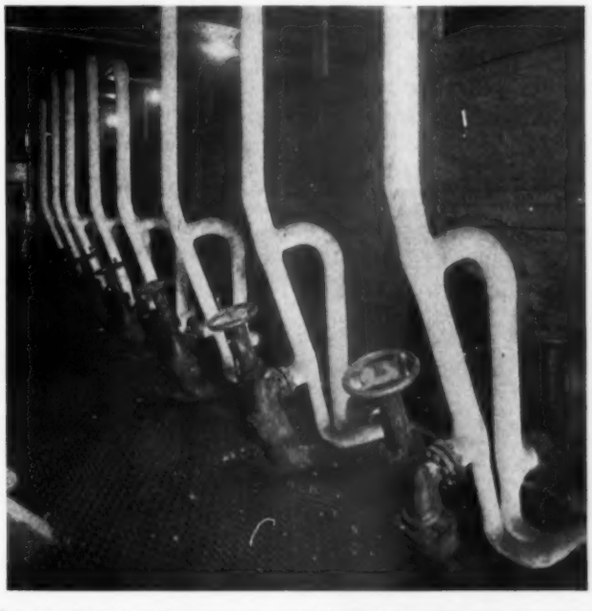


Fig. 9—Roof soot blowers; cooling air to plenum chamber passes through pipe at left (not shown)

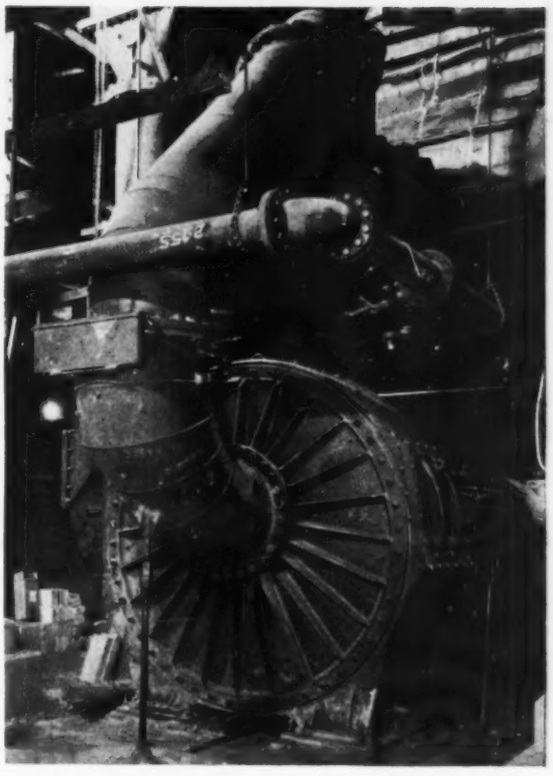


Fig. 10—No. 2 mill, coal downtake and coal feed to burners

The boiler control boards consist of a benchboard and vertical panel, as shown in Fig. 12. On the benchboard are mounted the controls for mills, feeders, fans, ignition torches and feedwater, together with position indicators for these controls. This board also contains indication and control of the burner and bypass damper positions. The vertical panel is adjacent to the benchboard and is used for mounting the meters, gages and indicators upon which the operator relies for guidance.

Feedwater Treatment

The boiler feedwater is essentially condensate. As makeup is required, it is normally fed into the low-pressure boilers. However, if this proves insufficient, the makeup is then fed to the high-pressure unit. To pretreat the makeup, a 50,000-lb per hr Permutit softening plant is provided, consisting of a hydrogen Zeo Karb exchange unit (regenerated by sulphuric acid) and a sodium Zeo Karb unit (regenerated by salt brine). The makeup water is passed through both units in parallel. The hardness-free effluents of both units are then mixed and cascaded through a degasifier which removes most of the carbon dioxide from the water. After treatment, the water is stored in a storage tank which is sufficiently large to require only intermittent use of the treating plant.

In addition to presoftening the water, provision is made to treat chemically all feedwater to the high-pressure boiler as required to maintain the proper boiler water conditions. For this purpose, Proportioneers, Inc., motor-driven duplex variable displacement chemical feed

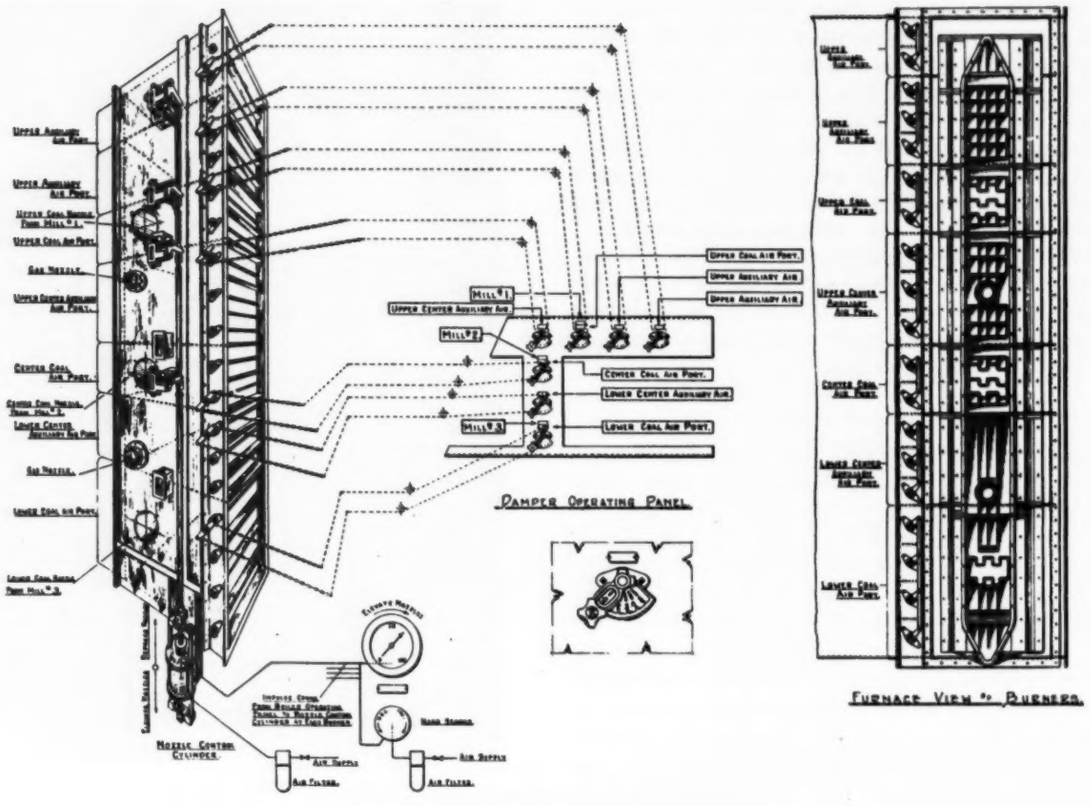


Fig. 11—Burner and control arrangement

pumps have been provided to feed caustic into the feedwater system ahead of the economizer and to feed tri- or di-sodium phosphate directly into the boiler drum.

The continuous blowdown system for this boiler and future high-pressure units consists of a high-pressure flash tank which flashes 33 per cent of blowdown in the station 200-lb steam system and a low-pressure flash tank which receives the drains from the high-pressure tank and flashes 17 per cent of such drains into the station auxiliary exhaust system. The system has a capacity of 150,000 lb per hr of blowdown which can be fed to the flash tanks through a system of orifices designed for various blowdown rates. The flash tanks were made by the Babcock and Wilcox Company. Each tank is provided with a number of cyclone separators arranged so as to remove effectively the moisture from the flashed steam.

In the design of this unit, it is felt that a trouble-free installation, easy and convenient to operate, with a high availability has been accomplished.

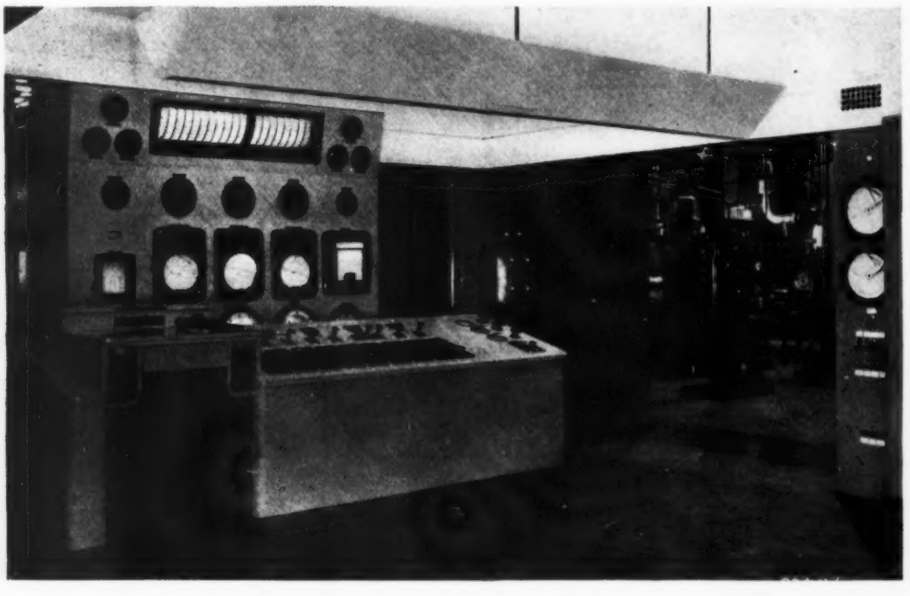


Fig. 12—Boiler control benchboard and panel valve control; alarm panels shown at right

CORROSION by Liquids

By R. C. COREY

Combustion Engineering Company, Inc.

A review and discussion of the theory of corrosion, in the presence of moisture, of metals commonly employed in power plant practice, as considered from the thermal and electrochemical standpoints, by numerous investigators references to which are given in the text. A subsequent article will deal with the scaling and oxidation of metals at high temperatures.

AT EVERY point in a steam-generating cycle where iron, steel, copper or alloys of these metals are in contact with feedwater, boiler water, steam, steam condensate or raw cooling water there exists a natural tendency for the metals to oxidize and revert ultimately to the oxides from which they were derived. Thermodynamically, it can be shown that corrosion is a chemical process in which metals tend to degrade to a lower form of energy—the degree of degradation being measured in terms of the change in free-energy, a quantity that is a function of the heat of formation of the metal from its oxide, the net change in entropy of the system, and the absolute temperature.

From a practical standpoint, it is of primary importance that the rate and the distribution of attack on a metal be known for the specific conditions under which it is to be used. Although thermodynamics is of invaluable aid in determining the tendency or the probability of corrosion, only experimental work, either on a laboratory scale or plant tests, will afford information on the rate of attack and indicate whether pitting, grooving or other forms of localized attack will occur. This fact is often overlooked in the design of equipment, and corrosion literature reveals many examples of serious metal failures where dissimilar metals were injudiciously placed in contact with each other, or where consideration was not given to the effect of alternating stresses in lowering corrosion resistance.

Inasmuch as the mechanism of corrosion of the base metals such as iron and copper, which are most generally used in power plant practice, is fundamentally the same, and the effect is one of degree rather than kind, these metals will receive primary consideration.

Theory

Corrosion reactions may be divided into two general classes. There are those in which the corroding metal replaces hydrogen or some other metal from the solution with which it is in contact, and there are reactions in which the metal combines directly with a non-metallic phase such as steam, oxygen, or gaseous sulphur compounds such as hydrogen sulphide, sulphur dioxide or sulphur trioxide. The first class of reactions may be exemplified by the corrosion of the common metals in water, acids or alkalis. The second class, equally as important but less well understood, considers the scaling or oxidation of metals at high temperatures in the presence of the gases mentioned. Both classes of reactions are oxidation processes. This review will consider only the first class, with particular reference to power plant practice.

Mechanism of the Replacement Type of Corrosion

On the basis of corrosion research and experience there are a few general aspects to the problem of corrosion of this type which form the foundation of what might be considered almost as laws governing the corrosion of base metals; certainly they comprise a basic outline of corrosion behavior. The most important ones follow:

1. Surface films on a metal, present usually as an oxide of the parent metal, are important in controlling the rate and the distribution of attack. In certain cases, materials deposited on the metal also afford an impervious barrier to the corrosive medium. The latter is a factor of importance where the temperature does not exceed about 150 F.

2. The initial corrosion rate of a metal usually is extremely high and decreases rapidly as the surface becomes coated with an oxide film or as polarization, a factor to be discussed later, occurs. It has been noted that the corrosion rate of many highly corrosion-resistant metals or alloys, during the first few moments of contact with the corroding medium, is as high as that of iron or steel.

3. The rate of corrosion increases with temperature and, to a certain point, with the velocity of the liquid with respect to the metal.

4. Dissimilar metals in contact in a liquid comprise a galvanic cell which, according to circumstances, may either affect protection of the metal or increase its rate of corrosion to a dangerous degree.

5. The relative areas of the dissimilar elements of a cell, whether they are contiguous with one another as in a two-phase alloy, or separated and connected externally, affect the rate and distribution of corrosion to a marked degree.

6. Alternating stresses in the presence of most liquids will reduce the endurance limit of a metal to an unpredictable degree.

7. Variations in the concentration of solutes in the corroding medium in contact with the surface of the exposed metal will increase the rate of corrosion. This effect will be discussed more fully in connection with the role of dissolved oxygen.

In 1903, Whitney[1] proposed an electrochemical theory for the corrosion of metals which today, despite the vast research work since that time, has gained in stature and forms the basis for the theory of corrosion in the presence of moisture. He considered that corrosion was associated with the flow of electricity resulting when certain iron atoms at the metal-liquid boundary each lose two electrons and become ferrous ions. The liberated electrons then are accepted by the hydrogen ions in the water or acid, reducing them to hydrogen atoms, which under suitable conditions combine to form molecular hydrogen which escapes as a gas. These reactions may be represented as follows:

$$Fe - 2e \rightarrow Fe^{++} \quad (1)$$

$$2H^{+} + 2e \rightarrow 2H \quad (2)$$

adding

$$Fe + 2H^{+} \rightarrow Fe^{++} + 2H \quad (3)$$

and

$$2H \rightarrow H_2 \quad (4)$$

This mechanism is fundamental, but there are numerous factors which affect the rate of each of the above reactions and determine the nature of the corrosion products. Thus, in acid and in neutral solutions, other things being equal, the overvoltage of hydrogen on the metal is an important rate factor. In certain instances, as in the choice of an inhibitor, use is made of the fact that the overvoltage may be made very high, thus stifling reaction (4) and reducing the rate of corrosion. Overvoltage is the difference between the potential required to evolve hydrogen from a metal in a given solution and the reversible potential of the same metal in the same solution when the metal is saturated with hydrogen. Essentially, the hydrogen overvoltage of a metal is a measure of the reluctance of hydrogen to discharge as a gas on that metal. Platinized platinum has the lowest and metals like zinc and tin have the highest hydrogen overvoltage in acid solutions. Many theories for overvoltage have been proposed but no single theory is wholly acceptable. The primary factors affecting the overvoltage of a specific metal are the physical condition of the surface and the nature of the solution.

To state the case more generally, all metals when placed in pure water ionize to a certain extent, the tendency to ionize being determined by the "electrolytic solution pressure" which has a unique value for each metal in a given environment. For example, zinc and aluminum each exhibit a greater solution pressure than iron. The fact that aluminum has better corrosion resistance than iron in certain media is the result of the formation of a tenacious, protective, self-repairing film of aluminum oxide. The potential of a metal with respect to the solution, measured under conditions of zero current (potentiometrically) is a measure of the solution pressure, and it may be thought of thermodynamically as the work necessary to transfer ions from electrolytic solution pressure P, to the opposing pressure p of the metal ions in the liquid. Nernst expressed these relations as follows:

$$\int V dp = RT \int \frac{dp}{p}$$

integrating, work $= RT \log_e p + C$

the electrical energy involved $= nFE$

equating $nFE = RT \log_e p + C$

at equilibrium $P = p$

then $$E = \frac{RT}{nF} \log_e \frac{p}{P}$$

or $$E = \frac{0.002}{n} T \log_{10} \frac{p}{P}$$

where P = electrolytic solution pressure
p = pressure of ions in solution
R = gas constant
T = absolute temperature, °K
F = 96,500 coulombs
n = valence of metal
E = volts

In the past, a number of writers on corrosion theory seem to have erred in utilizing the "electrochemical series," an arrangement of the metals in the order of their potential against a solution of specified concentration, to predict the corrodibility of a metal. The fallacy of this practice is well described in more recent tests and articles on the electrochemistry of corrosion. On the other hand, measurements of the change of potential with time of a metal in a given environment affords a useful and accurate prediction of the probability of corrosion under the conditions of the test.[2,3,4] Such measurements have been used extensively in the development of non-ferrous metals for use in surface condensers where mechanical and chemical effects exert a destructive effect.

An equally important concept of the electrochemical theory of corrosion, forming the physical basis for the foregoing equations (1) and (2) and determining the rate of corrosion, is that the surface of a metal cannot be perfectly homogeneous if corrosion is to occur. It is obvious that ferrous ions and hydrogen atoms cannot occur on a metal surface simultaneously. Therefore, it is necessary that there be physical or chemical differences on the surface and that there be areas where the solution pressure is greater than elsewhere on the surface. This heterogeneity gives rise to innumerable small galvanic cells composed of minute anodes and cathodes, the former being where ions are formed and the latter where ions are reduced.

Consideration of the following factors will show that any one or combination of them is unavoidably present in a metal surface.

1. Localized strains causing distorted crystal lattice areas.
2. Roughness or pitting.
3. Non-uniform composition of the metal or non-metallic inclusions such as oxides, sulphides, slag stringers.
4. Difference in the orientation of the crystal lattice of each grain.
5. Grain boundaries.
6. Presence of more than one metal phase, such as carbides in 18–8 and beta brass in an alpha brass matrix.

[1] "The Corrosion of Iron," W. R. Whitney, *Journal Am. Chem. Soc.*, **25**, 394 (1903).

[2] "Time-Potential Curves on Iron," T. P. Hoar, and U. R. Evans, *Journal Iron & Steel Inst.*, **126**, 379 (1932).

[3] "Causes of Corrosion Currents," R. B. Mears and R. H. Brown, *Ind. Eng. Chem.*, **33**, 1001 (1941).

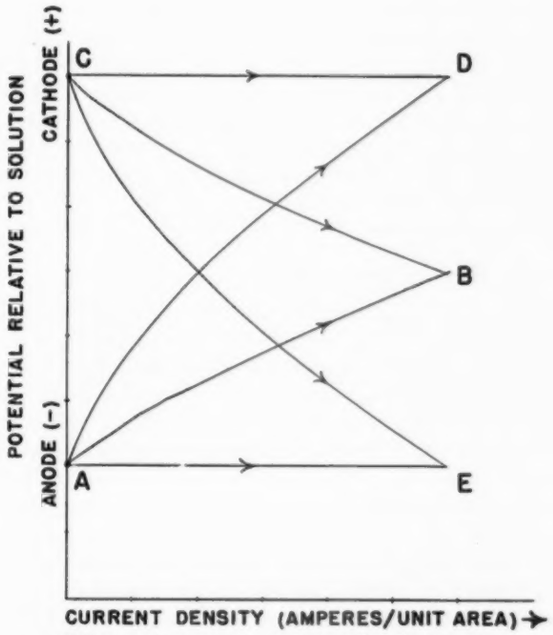
[4] "Some Observations of the Potentials of Metals in Sea Water," F. L. LaQue and G. L. Cox, *Proc.* A. S. T. M., **40**, 670 (1940).

7. Differential thermal treatment of the surface; such, for instance, as the effect produced by improper heat treatment of welds in which weld metal may be different in structure from base metal.
8. Small, discontinuous patches of scale or deposit on the surface.
9. Non-uniform grain size.

It may be appreciated from this list, which is by no means complete, that the only condition which could be considered as approaching a homogeneous metallic surface would be a single crystal of a fully annealed, one-hundred per cent pure metal—a highly ideal condition.

The potential difference between the anodes and cathodes thus formed on a metal varies markedly with the current flowing between them and this change in potential with current is known as *polarization*,[5, 6] another factor mentioned previously as determining the rate of corrosion.

Polarization may be represented schematically by the accompanying diagram. When no current is flowing,



Schematic representation of polarization

the potential difference between the anodes and cathodes is a maximum but when current starts to flow either the potential of each decreases (*ABC*), or only cathode polarization occurs (*AEC*), or only anode polarization occurs (*ADC*). There are rare cases where little or no polarization occurs and the potentials would follow *CD* and *AE*. The final potential at points *D*, *B* or *E* represents the overall potential of the metal against the solution. The current coordinate at any point is a measure of the rate of corrosion and where it is possible to determine it, a direct measure of corrosion rate is afforded.

The magnitude of the current at any instant is dependent upon the following variables: the open-circuit potential difference between the local anodes and cathodes (*A* and *C*), the anode and cathode polarization, and the electrical resistance of the solution between the anodes and cathodes. These quantities may be expressed as follows:

$$I = \frac{E - (E_a + E_c)}{R}$$

where E = open circuit potential difference of anodes and cathodes
E_a = anodic polarization
E_c = cathodic polarization
R = resistance of liquid path

The extent to which the anodic and cathodic areas polarize depends upon many factors, the most important of which are (*a*) hydrogen overvoltage; (*b*) the nature of the solution, that is, if it contains oxidizing agents or enhances film formation; (*c*) the ratio of the area of the anodic to the cathodic areas; and (*d*) the nature of the corrosion products formed on the metal.

The practical aspects of control of corrosion by the control of polarization and associated factors may be found in the use of corrosion inhibitors, the properties of which will be discussed later, and the addition of small quantities of aluminum, arsenic, phosphorus or antimony to certain non-ferrous alloys, such as alpha brass tubing for heat-exchanger and surface-condenser service. The inhibitors increase the resistance of the liquid path between the local anodes and cathodes, increase polarization of the anodes and cathodes, and decrease the open-circuit potential difference between the anodes and cathodes. The elements added to brass function primarily in the last category.[7, 8]

To this point, the general theory of the replacement type of corrosion has been considered. Most of the material covered has been concerned with the primary factors of corrosion related to the metal alone. Of equal importance, and in many instances, of primary concern, are factors related to the environment. It is not possible in the present discussion to cover all possible cases of contact of a metal with acids, bases or salts; therefore, for the present case it will be sufficient to consider the general effects of acid, neutral and alkaline solutions. Closely related to these three conditions is the role of dissolved oxygen in the corrosion of iron; hence this phase of the problem will be covered first.

Corrosion in Various Media

Effect of Dissolved Oxygen

Dissolved oxygen in the corroding medium, particularly in the case of iron or steel in contact with neutral or slightly acid or slightly alkaline solutions, increases the rate of corrosion to a marked extent. It would be misleading to attempt to present a quantitative expression to show the relative effect on the corrosion rate of iron or steel of water containing oxygen as compared with de-oxygenated water, as there are numerous other variables which would require to be evaluated and such an expression would refer only to a specific case. Qualitatively it appears, however, that the rate of corrosion of steel in neutral water varies linearly with dissolved oxygen up to a concentration of about 5 ppm. The boiler operator well knows the destructive effect of dissolved oxygen on economizer and boiler surfaces and every effort

[5] "Measurement of Irreversible Potentials as a Metallurgical Research Tool," R. H. Brown and W. L. Fink, *Trans. A. I. M. M. E.*, T. P. 1234.
[6] "Protective Coatings for Metals," Burns and Schuh, Reinhold Pub. Corp., 1939.
[7] "The Dezincification of Alpha Brass with Special Reference to Arsenic," F. W. Fink, *Trans. Electrochem. Soc.*, 1939.
[8] "Corrosion of Copper and Alpha Brass," J. H. Hollomon and J. Wulff, *Trans. A. I. M. M. E.*, T. P. 1311 (1941).

is made to remove it by chemical or mechanical means.

Dissolved oxygen has a two-fold effect in neutral and alkaline solutions, acting to depolarize both the anodic and cathodic areas. Although there is no general agreement on the actual mechanism of this action, it is best thought of as one of electron-transfer and may be represented as follows:

Net cathode reaction: $O_2 + 2H_2O + 4e \rightarrow 4(OH)^-$ (6)

$4H^+ + 4OH^- \rightarrow 4H_2O$ (7)

Net anode reaction: $4Fe^{++} - 4e \rightarrow 4Fe^{+++}$ (8)

Overall reaction: $4Fe + 3O_2 + 2H_2O \rightarrow 2Fe_2O_3 \cdot H_2O$ (9)

"Oxygen concentration cells" or "differential aeration" are more or less synonymous expressions that are often mentioned in corrosion literature and they refer to conditions where a difference in oxygen concentration exists between two areas on the surface of a metal. Corrosive attack under such conditions usually is manifested by extremely intense, localized loss of metal. Pitting and grooving are the result. The effect of a difference in oxygen concentration may be demonstrated by measuring the potential difference of two iron electrodes, one being placed in water containing 1 ppm of dissolved oxygen and the other in oxygen-free water, connecting both half-cells by means of a salt bridge which permits the flow of current but prevents mixing of the solution. A large emf will be generated, the solution containing the least oxygen being the anode and therefore the point where most corrosion will occur. Mears and Brown[9] noted an emf of 40 millivolts between two steel electrodes placed in 10 per cent NaCl, the liquid around one electrode being free of oxygen and the other aerated with a stream of air at a rate of 1300 cc per min.

Differential aeration or oxygen concentration cells occur under the following circumstances with deleterious effects on the metal:

1. A laid-up boiler partly filled with untreated water and improperly sealed against atmospheric infiltration may be expected to show severe attack at somewhat below the water-line.[9]

2. Beneath a small patch of scale, or within a pit in the metal, the oxygen may be consumed and form a corrosion product that impedes the diffusion of oxygen from the surrounding liquid. Thus, where the oxygen concentration is least, the metal will be most anodic and as the pit becomes deeper the attack becomes more intense.

Corrosion in Acid Solutions

Considering the case of iron and steel and corrosion in acid solutions, where pH is lower than 5, anodic and cathodic polarization and dissolved oxygen do not affect the rate of solution materially and corrosion proceeds as follows:

$$Fe + 2H^+ \rightarrow Fe^{++} + H_2$$

hydrogen being released freely.

The change in free-energy of the above reaction in calories is

$$\Delta F = 20{,}350 + 1365 \log \frac{(a_{H^+})^2}{(a_{Fe^{++}})}$$

where (a_{H^+}) and $(a_{Fe^{++}})$ are the effective concentrations (activity) of these ions. In the *absence of oxygen*, equilibrium would be reached theoretically when the ratio $(a_{H^+})/(a_{Fe^{++}}) = 10^{-7.45}$. However, due to the formation of a film of ferrous hydroxide on the metal from the reaction of the ferrous ions with the hydroxyl ions as the pH increases, the rate of solution ultimately is governed by a constant ratio of $(a_{Fe^{++}})/(a_{OH^-})$ which limits the a_{H^+}.

In practice, acidic corrosion occurs primarily in condensing equipment as the result of excessive amounts of CO_2 in the steam. Where the proper non-ferrous metals are used, the attack may be negligible but in the case of iron and steel parts following traps, as in radiator returns, grooving and pitting will occur close to the point of condensation; that is, where the buffer capacity of the condensate is lowest and an optimum temperature exists. Condensate high in CO_2 and flowing in a partly filled, improperly sloped pipe will cause corrosion without any appreciable solid corrosion products being formed and the pipe usually will be found to be grooved. Increasing the slope of the pipe or installing a vertical run after the trap and maintaining the trap seat in good order to prevent trickling of condensate tends to minimize pipe losses where the CO_2 cannot be controlled.

Another source of acidic corrosion may be found in feedwater lines where water high in magnesium and chloride ion is increased in temperature, hydrolysis of the salt occurring to yield an acid water. Deaeration without increasing the pH of the water after the deaerator may make the condition worse through the removal of bicarbonate ion which has a buffering effect.

Corrosion in Neutral Solutions

Although it is not accurate to refer to solutions whose pH is other than 7.0 as neutral, it is convenient in the present case to consider neutral waters to lie between 6.5 and 7.5, as, from the standpoint of corrosion mechanism and rate, the difference is not appreciable in this range.

The corrosion of iron and steel in unbuffered, O_2- and CO_2-free water of pH = 7.0 is rarely encountered in practice but its study is of great importance to an understanding of the fundamental mechanism of corrosion. Early work by Shipley and McHaffie[10] indicated that iron, under the above conditions, at room temperature and if given sufficent time, would corrode until the pH had risen to 9.6 due to the formation of ferrous hydroxide, and the corrosion then would cease. Doubt was cast[11] on this mechanism for several reasons and subsequent work indicated that under such conditions, where iron reaction vessels were used instead of glass, the final pH would be about 8.0 and that Fe_3O_4 and H_2 were the end products. Hydrogen appeared to be evolved continuously and stopped only when the Fe_3O_4 covered the surface of the iron so effectively that water no longer came into effective contact with the metal. Thermodynamical calculations corroborated these findings.[12]

For years it has been general practice to treat feedwater to pH of 9.6 to prevent corrosion, this value having acquired wide adoption as the result of Shipley and McHaffie's work. It has been found, however, that corro-

[9] "Water-Line Corrosion," U. R. Evans, *Journal Soc. Chem. Ind.*, March 13, 1936.

[10] "The Relation of Hydrogen Ion Concentration to the Corrosion of Iron," J. Shipley and I. McHaffie, *Canadian Chemistry and Metallurgy*, 8, 121 (1924).

[11] "The pH, Dissolved Iron Concentration and Solid Product Resulting from the Reactions of Iron with Pure Water at Room Temperature," R. C. Corey and T. J. Finnegan, *Trans. A. S. T. M.*, 39, 1242 (1939).

[12] Discussion of article by Corey and Finnegan[11], J. C. Warner and D. S. McKinney, *ibid.*

sion of iron and steel in oxygen-free water may occur at pH values in excess of this, particularly where the temperature is high—a fact which indicates that a protective film of ferrous hydroxide may not be present. It would seem therefore that although the rate of corrosion of iron and steel in oxygen-free water takes place at a very low rate at pH values above 9.0 (measured at 25 C or room temperature), higher temperatures require a somewhat higher pH value for the same degree of protection.

The overall reaction of iron in pure water, is believed to be

$$Fe + H_2O \rightarrow Fe_3O_4 + H_2$$

Corrosion in Alkaline Solutions

Although the rate of corrosion of iron may be shown to decrease as the pH increases, there is a limit above which severe corrosion may occur under certain conditions. It has been mentioned that a film of Fe_3O_4 on a metal is generally a limiting factor in the rate of corrosion; therefore anything that will remove this film may lead to serious corrosion by promoting formation of more oxide. Iron oxide, like aluminum or zinc oxide, has amphoteric properties; that is, the oxide will dissolve in a high concentration of hydroxyl ion to form complex negative ions (oxyanions) which in the case of iron are believed to be meta hypoferrite ion $(FeO_2)^-$.[13] This ion exists only in an environment of high concentration of hydroxyl ion and will, upon dilution, cause Fe_3O_4 to precipitate and produce a fine suspension of the oxide in the water.

Some work with anodically polarized iron, to produce a passive surface through the formation of a very thin film of Fe_3O_4, showed that 16 per cent NaOH, at the boiling point, restored the activity of the surface indicating the attack of the oxide. Also, iron powder placed in 50 per cent NaOH and boiled for a few hours will produce an equilibrium amount of dissolved iron—about 0.4 per cent.

Cases of severe pitting of steam-generating surfaces and the occurrence of large amounts of Fe_3O_4 as a sludge in drums and headers may result from caustic in boiler water concentrating on high-evaporative surfaces, as sludge-covered areas, and in capillary spaces in rolled and riveted joints. Where such areas are washed intermittently by the main body of the boiler water, dilution occurs and magnetic iron oxide is precipitated as a suspended solid.

Frequent mention has already been made of pitting—a form of localized attack found in economizers, heaters, water-wall tubes and surface condensers. A single pit, deep enough to penetrate the tube wall, will render a tube useless that otherwise may be in excellent condition, and it is for this reason that it is misleading to express corrosion rate in terms of weight loss per unit area per unit time or inches penetration per year unless the attack is distributed evenly over the exposed surface.

Pitting occurs when minute breaks occur in an otherwise protected surface permitting the corroding liquid to concentrate the attack in a relatively small area. This is particularly the case with condenser tubes where a protective film of oxide of almost infinitesimal thickness is destroyed by the action of high-velocity gas bubbles in the cooling water which collapse in the tube entry causing "inlet-end corrosion."[14] In a similar manner, pitting occurs frequently where hot, strongly alkaline solutions attack iron, the film of Fe_3O_4 breaking at a few isolated points on the surface to start pits. It is important to note that once a pit has started, secondary factors tend to accelerate attack within the pit and it is self-perpetuating.

Another cause of pitting is the presence of an inhomogeneity in the metal. A typical example is the severe pitting of improperly heat-treated austenitic steels, such as 18–8, in which undissolved carbides cause impoverishment of the chromium concentration in the metal adjacent to the carbide particles. This sets up a metallic concentration cell, the area adjacent to the carbides being anodic. In this particular case the damage is severe as the carbides usually segregate along the grain boundaries and intercrystalline cracks occur. Excessive oxides in copper tubing used for heaters set up local anodes which lead to pitting. Oxygen-free copper, copper-nickel alloys and special bronzes find use for such service. In the cases mentioned it is illustrated that the heterogeneity in the metal may be anodic or cathodic to the parent metal with equally disastrous results; in one case attack occurring adjacent to the heterogeneity, and in the other the foreign particle dissolves out, leaving a pit.

In general, protection against corrosion may be achieved by using more corrosion-resistant metals; or applying suitable protective coatings to the metal; or by making the environment less corrosive.

Control of the environment often is more expedient and economical. Thus, in the power plant pH control and degasification are the most common means for protecting iron and steel surfaces. In circulating systems which operate at temperatures below about 150 F, materials known as inhibitors are used. Inhibitors may be inorganic salts such as sodium chromate which, in neutral and alkaline solutions, acts as an anodic polarizer and stifles corrosion, or they may be complex organic compounds, the most common being nitrogen-bearing substances such as aliphatic and aromatic amines, and heterocyclic compounds like pyridine, quinoline and acridine. It is believed that the organic ions attach themselves to the cathode areas on the metal through the nitrogen group and prevent hydrogen from being evolved—this primarily being a process of cathodic polarization.

As a word of caution, it should be mentioned that, under certain conditions, serious pitting has been known to occur where chromate is added as an inhibitor, its action being rather that of an accelerator. Therefore, insufficient chromate or too low alkalinity is to be avoided.

Textbooks on Corrosion

"Metallic Corrosion, Passivity and Protection," U. R. Evans, Edward Arnold and Co., London, 1937.

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"Protective Coatings for Metals," Burns and Schuh, Reinhold Publishing Corp., 1939.

"Protective Films on Metals," E. S. Hedges, Chapman and Hall, London, 1932.

[13] "Anionic Iron," R. Scholder and H. Weber, *Angewandte Chemie*, 16, 255–266(1936).

[14] "The Corrosion of Condenser Tubes," R. May, *Journal Inst. of Metals*, 40, 155 (1928).

How to get the most out of your

CROSBY RELIEF VALVES

NO. 4—MACHINING VALVE SEATING SURFACES

If a valve seat has been severely damaged or if through continuous maintenance practice the seat has been lapped away, remachining may be necessary. The care and workmanship exercised in this operation can vitally affect the type and length of service rendered by the valve.

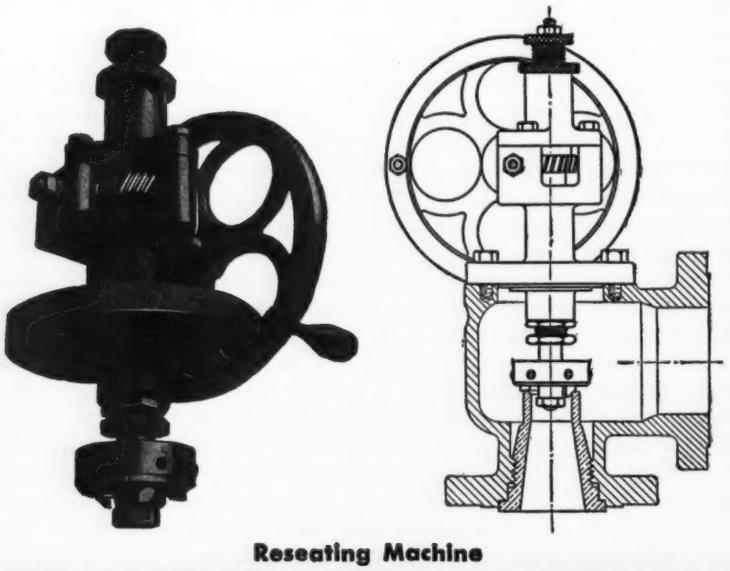
Both seating surfaces of Crosby nozzle type relief valves are flat and therefore easy to remachine. Briefly, the procedure we recommend is as follows.

Machining the Disc—

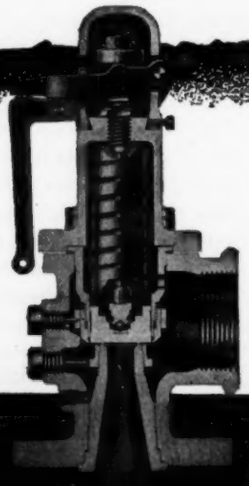
The disc should be chucked in a lathe and trued with the outside edge and face. After the disc is properly trued, the seating surface should be machined, taking very light cuts. Tool marks, drag, etc. can be kept to a minimum by use of a sharp tool and plenty of cutting oil. When the seating surface is machined to a smooth finish the other respective contours should be restored. It is essential that this surface be exactly perpendicular to the axis of the disc. When the machining operation is complete, the desired finish can then be obtained with a cast iron lapping block and grinding compounds.

Machining the Nozzle—

Refinishing the nozzle seat in some valves often requires complete dismantling before the seat can be machined. For this reason Crosby has designed a portable milling machine which greatly simplifies this operation. This machine is equipped with adapter flanges and various sizes of cutters—allowing it to be used on several different sizes and styles of Crosby relief valves. It will do the work much more easily and accurately than can be done on a lathe, since a form cutter is used which cuts a new seat to exact dimensions. The machine is obviously a time saving device and will at the same time permit a much better machining job with a minimum amount of required skill.



Reseating Machine



No. 4 of Crosby valve maintenance "tips" for improving valve performance and increasing valve life.

Crosby manufactures a complete line of relief valves. They operate accurately, stay tight, have high capacity and low maintenance.

CROSBY STEAM GAGE and VALVE COMPANY

10 ROLAND STREET, BOSTON, MASS.

Facts and Figures

The present daily demand for crude oil produced in the United States is well over 4 million barrels.

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When burning coal that has been dust treated with hygroscopic salts, care should be taken to avoid corrosion of stoker parts.

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In the last twelve months 72,000 men have been killed or injured in coal mines in the United States, according to Secretary Ickes.

•

About 1600 women are now employed in various capacities at British power stations, some of whose duties involve operation and maintenance.

•

Turkey is said to have large deposits of bituminous coal and lignite, but under government ownership and supervised operation the output is relatively small.

•

Nearly 40,000 enemy patents have been taken over by the Alien Property Custodian and are now available on nonexclusive licenses to small as well as large organizations engaged in war work.

•

Reports from the Federal Power Commission show that the production of electric energy for public use during June 1943 increased 19.3 per cent over that of June 1942. The corresponding peak demand was up 15.8 per cent.

Interconnection recently received a severe test and was not found wanting when a small oil fire caused the forced outage for some hours of two 160,000-kw turbine-generators in one of the power stations in New York City. The load was immediately picked up, without line disturbance, by other systems supplying the Northeast Power Pool.

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Shortage of valves of various types a few months ago was holding up completion of a large number of ships. At that time the demand for machine tools fell off and WPB was able to switch enough valve orders to the machine tool builders to completely wipe out the deficiency.

•

Extensive use of hydrogen cooling for large generators represents a marked contribution to the conservation of critical materials. This is because the superior cooling properties of hydrogen and reduced windage losses permit greater output with a given amount of metal, especially where the pressure of the gas is raised to about 15 lb gage.

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We hear much about the employment of "Radar" to detect the approach of enemy planes and surface vessels. This property of certain radio signals to bounce back from objects in their path at a definite measurable speed, from which distance can be determined, was first discovered by scientists in the U. S. Naval Aircraft Laboratory in 1922 and has been under development ever since. Foreign work in this field was predicated upon this early discovery.

Photo through courtesy of The Austin Co.

Air compressors which serve the assembly plant of the Douglas Aircraft Company at Chicago. The boiler house in which this equipment is located is primarily of timber construction, even the floor has wooden grills in place of steel.

Separation and Transportation of Coal Dust as Pulverized Fuel

ABOUT 1930, because of the difficulties encountered with fine coal in cleaning plants, dust collectors came into use. However, disposal of the collected dust presented a problem and the logical thing was to dispose of the dust in some useful and practical manner outside of the tipple.

As a practical matter, this can be done in one or both of two ways; either by consuming the dust at the mine's own power plant or by marketing the dust direct to the consumer. The latter method not only offers the greatest opportunities, but is the most important, because of inequalities that may exist between the quantity of dust collected and the consuming capacity of the mine's power plant.

In considering the more important marketing possibilities, we are confronted immediately with the problems connected with the handling and transportation of so fine a material. It is this problem, rather than the problem of finding new markets, that has been responsible for the lack of progress in the matter of dust disposal.

Potential Markets

In general, the potential market outlets would include any operation of which the pulverization of coal is a necessary part. To be more specific, a few of the better known operations of this type include: colloidal-fuel plants, briquetting plants, "sea coal" distributing plants, water-purification plants and, obviously, pulverized-fuel power plants. The last mentioned, because of their greater number, their type of equipment and their greater consuming capacity, probably offer the most practical outlet.

Development of a burner to use pulverized coal for small commercial and domestic heating has definitely been held back because of unavailable fuel. In trying to compete with other fuels, a number of small unit pulverizers and burners have been developed, but have been found impracticable because of noise, adjustments and the dangers involved when they are placed in the hands of the average consumer. Practical burners of the storage-bin type have also been developed but are unmarketable because of the lack of pulverized fuel. If this were available to local dealers in carload lots, these burners would be practical, because coal dust can be handled in equipment similar to that now used in distribution of fuel oil. Coal dust can be handled from tank truck, through hose or pipe, to the consumers' bins with all the convenience and cleanliness of oil fuel.

Dedusting System

During the past several years the Carter Coal Co. has been collecting dust at one of its mines in the Pocahontas No. 4 seam, McDowell County, West Virginia. This is a low-volatile coal, low in moisture and very friable. At that mine, the dust-collecting system was not installed in combination with any washing or cleaning operation, but was meant to improve the prepared sizes and to eliminate hazardous working conditions around the tipple.

In a paper before the American Institute of Mining and Metallurgical Engineers at St. Louis, H. C. Ray, Chief Fuel Engineer of the Carter Coal Co., reviewed what is being done by one mine in the disposal of the product of dedusting operations. This fine-mesh coal dust is handled in 50-ton lots direct to the consumer and is being burned under the boilers of a large utility power plant. The transportation and handling of such coal dust is discussed as are also its market possibilities. Following are excerpts from the paper which has just been printed and released by the Institute.

The system consists of a suction pickup, cyclone collectors, cloth collectors, a pulverizing mill and a Fuller Kenyon air-pump for handling the finished product through storage bins, which will be referred to as the "fine-dust bin," the "final storage bin" and the "coarse-dust bin." The dust is first picked up by suction from completely housed terminals in the tipple at strategic points in the coal flow. From these terminals it is conveyed through pipes to the cyclone collector, where the coarse dust is precipitated and passed down to the coarse-dust bin. The exhaust from the cyclone collector passes through a pipe to the baghouse, where all the dust is removed from the air by means of cloth screens; then the clean air is exhausted to the atmosphere. The dust from the baghouse is 200 mesh and finer, needs no further preparation and is taken by screw conveyor to the fine-dust bin.

The baghouse dust can be pumped from the fine-dust bin to the mine powerhouse, or over to the final storage bin. That from the coarse-dust bin can be pumped into the final storage bin, thence by gravity to the railroad car; or by gravity to a ball-mill pulverizer, where it is classified and ground to 100 mesh to zero. After pulverization it can be pumped either to the mine powerhouse or to the final storage bin.

For shipment to market the cars are of the type used for shipping cement, and the dust is simply loaded by gravity through flexible canvas tubes connected to the hatch openings in the top of the car.

Transportation

Probably the greatest restraining factor in the use and distribution of coal dust prepared at the mine is the problem of transportation. The smallest sizings of pulverized bituminous coal, in this case 100 mesh to zero, cannot be transported in ordinary railroad cars. When loaded, pulverized bituminous coal is well aerated, whether loaded by gravity or by means of compressed air. The result is that the material flows into the car and seeks its own level. This means that there is no difficulty in completely filling all spaces, regardless of the shape of the container. The vibration of the railroad car in transit causes the dust to pack down to a consistent mass, which will support the weight of a man. Hence the ideal car for transportation of this material is one that can hold enough aerated coal dust to meet the weight requirements of the railroads, so as to avoid freight charges in excess of those normally charged per ton of coal. Furthermore, the cars must be so constructed that they will prevent any pickup of moisture, loss through windage or loss through leakage. Also because of the nature of the material, the cars must be easy to unload, therefore should contain convenient outlets supported by a sloping bottom, equal to or greater than the angle of repose of the dust, which in some cases reaches as much as 60 per cent.

In Europe, particularly in England and Germany, the transportation of coal dust is an old story, and engineers there have developed two types of cars—a tank car and a car that carries two or three separate vertical round tanks or tubs. However, European conditions and railroad facilities are quite different from those in America.

The standard tank car may be filled easily enough but the average cubical content is not great enough to hold a satisfactory load even if vibration were applied during the loading process. Furthermore, there are not enough outlets in the standard horizontal tank car, and even if they were provided it would be impossible to empty the car completely.

The tub cars are not standard equipment in this country, therefore are not available.

Demand for bulk shipments of cement and other pulverized materials in this country caused the railroads to develop a car expressly for the purpose, commonly known as the cement car. During the depression years, the construction of these cars was retarded and most railroads do not have enough of them to satisfy the

ANALYSIS OF COAL DUST AS RECEIVED

Proximate Analysis		Screening Analysis, %	
Moisture, %	0.37	Through	
Volatile matter, %	16.35	200 mesh	93
Ash, %	6.70	100 mesh	97
Fixed carbon, %	76.58	60 mesh	99.6
Heat units, Btu	14,590	40 mesh	99.9
Sulphur, %	0.52		
Ash-fusion temperature, deg F	2350		
Ash-fluid temperature, deg F	2450		

demand. However, the trend in this direction makes it easier to solve the difficulty of coal-dust transportation because these cars are very satisfactory for the purpose. Since they were primarily designed for the transportation of cement, their capacity is generally about 50 tons, and this quantity probably would necessitate the use of vibrators when loading coal dust, in order to make a satisfactory railroad pay load.

Because of the increased demand for this type of car, at least one railroad has built cars having 70 tons capacity, which enables them to carry satisfactory loads of the lighter density materials such as pulverized coal dust. These cars are owned by the railroad that services the only mine from which bulk pulverized coal has been shipped successfully, and their performance has been entirely satisfactory.

Unloading and Consumption

In seeking a possible market for the 100 mesh to zero coal dust, the writer visited a number of pulverized-fuel plants conveniently located along the originating railroad and a contract was made for the use of the dust with a large utility company having a new and most modern unit pulverizer system.[1] After preliminary studies the necessary equipment for unloading, conveying and burning the coal dust was installed. This first experimental equipment consisted of a track unloading pit containing a Fuller-Kenyon pump, a 40-ton storage silo in the slack-coal bunker and a table feeder feeding to a unit mill pulverizer.

While the dust actually needs no further pulverizing, it was considered good practice to feed the coal through the unit mill, thereby eliminating the expense of further changes in the existing equipment, and also to ensure the pulverization of any coarse coal that might find its way accidentally into the original dust.

The hopper bottoms on the cement-type car are equipped with sliding gates. To overcome the difficulty of getting the dust to flow after it has settled into a solid mass during transit, a Syntron vibrator is attached to the side of the car and remains in operation until the car is unloaded. The gate outlets are arranged so that a canvas boot can be connected between the gates and the Fuller-Kenyon unloading pump. The contents of the car are conveyed from the pump through pipes to the overhead storage silo. From the silo the dust can be used alone to operate the boilers, or it can be used to supplement a pulverizer while it is in operation with slack coal. This installation was made in 1939, and no operating difficulty has been experienced in its use.

During the course of operation, an analysis was made of the coal dust as received. This was as shown above.

[1] See "Utilizing Refuse Coals at 12th St. Station, Richmond, Va.," by J. A. Reich, COMBUSTION, April 1941—EDITOR.

Air Preheater Corporation Wins Maritime Commission Awards

In recognition of outstanding achievement in the production of necessary equipment for the War Program, The Air Preheater Corporation has been awarded the Maritime "M" Pennant, the Victory Fleet Flag and Employees Merit Insignia by the Maritime Commission Board of Awards.

The presentation of these awards by Rear Admiral H. L. Vickery was the occasion of a colorful ceremony at the Company's plant in Wellsville, N. Y., on July 19 where, following the invocation by the Rev. M. Huyett Sangree, Mayor Thomas C. Martin made the welcoming address. Mr. W. L. Batt, Vice-Chairman of the War Production Board, and who at one time had been first Chairman of the Board of Directors of The Air Preheater Corporation, acted as master of ceremonies.

Acceptance of the Award was made by Mr. H. S. Marshall, Assistant Treasurer of the Company, and following the raising of the Pennant and the Victory Fleet Flag and the singing of the Victory Fleet Song by the Employee Color Guard, Superintendent M. A. Palmer contributed some timely and topical remarks.

Presentation of Merit Badges to several of the oldest employees, from point of service, was also made by Rear Admiral Vickery, and the ceremonies concluded with a short enlivened address by the President of the Company, Robert M. Gates, and a benediction by the Very Rev. P. C. Tracy.

The awards were made in recognition of the Air Preheater Corporation's achievement in furnishing Liberty ship boiler casings for the U. S. Maritime Commission.

Steam Turbine Auxiliary Equipment Curtailed

On July 28 the WPB issued a limitation order governing the supply of auxiliary equipment pertaining to steam turbines for land use. This order specifies that no producer shall install or deliver any of the following items: sheet metal lagging, asbestos, plastic or other high-temperature moulded insulation, or ornamental trim. Manufacturers may provide insulation materials (except asbestos blanket type) for application after erection of the turbine on its permanent foundation. The size of pressure gages is also restricted: not to exceed 6-in. diam. for steam gages, $4^1/_2$-in. diam. for oil gages and $4^1/_2$-in. for water gages if glands are of the water seal type. Duplicate gages or other instruments are also prohibited. Except for metering purposes, no pipe or tubing of monel metal or that containing 40 per cent or more of copper is allowed to be used for steam condensate or oil piping. Not more than one main oil cooler is allowed, nor more than a single full capacity auxiliary pump other than pumps for turning gears and hydrogen-cooling equipment. Special materials and features are also disallowed which are not customarily furnished by the manufacturer for the conditions under which the turbine is to operate.

William L. Batt, Vice-Chairman of the WPB, challenges the employees of The Air Preheater Corporation to continue their high production record. Seated at the front of the platform are R. M. Gates, President of The Air Preheater Corporation, and Rear Admiral Howard L. Vickery, Vice-Chairman of the U. S. Maritime Commission.

Denies Intent to Nationalize Coal Industry

With the Federal Government taking over operation of the coal mines, there were many who believed that this action presaged ultimate nationalization of the coal industry. However, the following excerpts from an address by Carl E. Newton, Deputy Coal Mines Administrator, before the American Mining Congress at Cincinnati on July 20, indicates no such intent and that nationalization would come about only if all other measures were to fail.

BECAUSE uninterrupted production must be maintained to produce coal to win the war, the Government took control of the mines. It did so because a set of circumstances had led to interruptions in coal production which imperiled the war program. The Government's job is to keep the machinery of coal production running. It is hoped that the operators and mineworkers can arrive at a solution of their differences which will enable them thereafter to cooperate in the production of coal without the intervention of Government machinery. I hope that such a solution is not far distant. The more prolonged Government control, the more critical will inevitably become the danger to the coal industry and to the Nation.

But, as a result of the recent work stoppages, the Nation has lost production. We must strive hard to make up for these losses. I believe it can be done.

By the Smith-Connally Act, Congress had expressed its will that the mines "shall be returned to the owners thereof as soon as practicable but in no event more than sixty days after the restoration of the productive efficiency thereof prevailing, prior to taking possession thereof." There is nothing that Secretary Ickes or I would rather do than turn your mines back to you tomorrow. Until we can, however, we have the duty to see that the mines are operated so that coal is produced to fuel our national war requirements.

I would not undertake to draw for this industry a blueprint of how to escape from its present dilemma. It would be presumptuous to do so. Once this industry brings unitedly to bear upon the solution of this critical problem the full force of the determination, intelligence and resourcefulness of which it is capable, I am confident that it can formulate the basis for restoration to its proper place in the American economy, permanently free of Governmental control; that a way out can be found. Of course, any agreement or solution that might be arrived at will be subject to the President's stabilization program and will necessarily be subject to review by all Government agencies having jurisdiction.

Production has increased progressively since the end of the most recent nationwide stoppage. The coal is coming out of the ground now and the Coal Mines Administration will do everything in its power to bring about increased production to the maximum possible with the manpower and facilities that are available. We intend to continue to rely primarily upon the cooperation of the industry—operators and mine workers—for the accomplishment of our objective. We have raised our sights for coal production to a higher level than we aimed at last year, namely, 65,000,000 tons of anthracite and 600,000,000 tons of bituminous.

As the war progresses, it will become increasingly difficult to maintain production requirements. Even with peace on the labor front, the task of maintaining production would grow progressively more difficult because of the increased strain of the war upon our economy.

The question that is being asked in the press of the nation is: Does this portend the nationalization of one of our basic industries? I shall try to answer that question as fairly as I know how.

Secretary Ickes and I are resolutely determined to resist any trend toward nationalization of the coal mines. Nevertheless, we cannot close our eyes to the facts. If this industry can achieve permanent peace in its labor relations, these apprehensions would soon be set at rest. But if unsettled conditions which precipitated this crisis should long endure, or if the Government should turn the mines back and have to take them over again repeatedly, then I don't see how one can reasonably expect to avoid a progressive tightening of Government supervision and control of mine operations. Government control would inevitably grow where conditions exist which bring public pressure for Government action. Can we turn Government control on and off with impunity?

Observe what has happened in Great Britain.

Laws prohibiting strikes, under heavy penalties, have failed to prevent them. The British coal industry has had many problems to deal with similar to our own, including high production costs, instability of prices, wages and employment. Over a period of years, unsettled conditions have called for a series of Governmental solutions.

His Majesty's Government now owns the coal reserves. It controls the operation of the mines and it allocates the coal to the consumers. It has poured millions of pounds of public funds into the industry. Yet the evils which were sought to be cured by the steps along the road to nationalization remain uncured. Today Great Britain's coal industry is not a free or competitive enterprise. And it has lost productive strength to the extent that the mines no longer can adequately meet war-expanded coal requirements.

In the light of the fact that Great Britain has traveled far on the road to nationalization of its coal industry, can we Americans afford to be complacent?

Since taking office on July 1, I have been subjected to many heavy and insistent pressures from various sources to do things which, in my view, would be a long step on the road to nationalization of the coal mining industry. You may be surprised when I tell you that some of the heaviest and most insistent of these pressures have come from members of your own industry. I have received dozens of telegrams from mine operators urging immediate advance of federal funds, and threatening to shut down their mines unless these funds are forthcoming.

Secretary Ickes and I have resolutely resisted all of these pressures. To date, the Coal Mines Administration has not advanced one dollar to any operator. Some mines have shut down, as they have in every year, and as they will continue to do so long as coal is mined. But aggregate coal production is creeping up, not sliding off.

However sympathetic we may be to these operators in their difficulties, are they so short-sighted that they cannot see what their demands for federal funds would lead to, if we complied with them? Easy money for one operator would create a torrent of demands from other operators.

If Uncle Sam should open wide his purse to the coal industry, then the coal industry would wake up some day and find out that it is in hock up to its neck to Uncle Sam. Can there be any doubt about it? It has been my observation that when a company is heavily indebted to its banker, the banker will tell that company pretty much what salaries and dividends it can pay and otherwise how it must conduct its business. "Who pays the piper calls the tune." That is as true of the taxpayers' money as it is of private funds.

I see no evidence yet and I hope I shall never see any evidence that the industry as a whole cannot fulfil its national responsibility for the production of coal without substantial use of public funds.

Secretary Ickes and I do not propose to be panicked into opening the flood gates of public moneys by the threat of mine shutdowns or by claims of Govern-

ment liability for operating expenses or maturing debt. We intend to continue to resist with determination the diverse pressures that would make the Coal Mines Administration play Santa Claus to the coal industry. Such pressures always look reasonable on their face. But all of us must be alert to look behind appearances and firmly resist such pressures because of where they will lead us.

Yet ridiculous rumors are abroad to the effect that Secretary Ickes and I are conspiring with various persons, named and unnamed, to nationalize the coal mines. Our actions are the best denial of these rumors.

No American could believe more profoundly than I in the American system of free competitive enterprise. I have served in Government office before and I have also been in business. I know well the formalism, the channels, the protocol, which must necessarily attend the effective discharge of Governmental functions. But Governmental functions are essentially regulatory, and hence are basically different in nature from business functions. The deliberative and regulatory machinery of Government produces delays and does not produce effective commercial results when applied to business objectives under *any* auspices. In business, Government procedures do not promote initiative, incentives or progress.

The strength and common good of this Nation—our whole future—lies in the preservation of the American concept of free men and free competitive enterprise. This concept is the thing which won our independence, the thing that has made this nation great.

Electronic Conversion of Power*

Use of the mercury-arc rectifier to convert alternating current to direct current is one of the earliest applications of electronics. Almost all power is generated today in the form of alternating current and most of this power is supplied to alternating-current loads. There are, however, some loads which must be supplied with direct current and others where direct current affords advantages which dictate its selection.

Direct current is necessary for electrochemical processes. Power for our war production of aluminum, magnesium and chlorine is supplied almost entirely by rectifiers, a high percentage of which are "Ignitrons." All conversion units sold to direct-current traction systems in recent years have been rectifiers. The mining industry is purchasing rectifiers almost exclusively to furnish direct current. The steel mills are purchasing rectifiers in increasing volume.

Ignitron rectifiers are also in service supplying power to general industrial loads and to small isolated loads in cities where the alternating-current network is replacing the Edison systems. Rectifiers are supplying high voltage for radio transmitting stations. They are applicable as variable ratio frequency changers to tie two d-c systems of different and fluctuating frequencies together.

If high-voltage, direct-current transmission should prove to be economical after the present problems associated with this form of transmission are solved, Ignitron rectifiers will undoubtedly find their place in the system.

Compared with electronic devices for communication and control, the principle of mercury-arc rectification for power conversion is not new. The rectification properties of a mercury-vapor arc were discovered and patented by Peter Cooper Hewett, in 1902. The development of the arc rectifier has been carried on since that time and is still in progress.

Current flows in a mercury arc with ease from the cathode to anode and with reluctance from anode to cathode. Occasionally a cathode spot will form on the anode that results in counterflow of current. This destroys the valve action of the rectifier, places a short-circuit on the rectifier transformer and permits reverse current to flow from the d-c system. This phenomenon is known as arc back and its prevention is the major rectifier design problem.

Although the causes of arc back are not definitely known there are certain design factors which will keep them at a minimum. Unfortunately, for a given type of rectifier, the measures taken to minimize arc back increase the rectifier losses and decrease the unit efficiency.

Dr. Joseph Slepian of the Westinghouse Research Laboratory and his associates, conceived and developed the Ignitron rectifier. This is a single anode tube rectifier with a synchronous ignition system. This type of rectifier has reduced the arc back rate and at the same time reduced the rectifier loss with resultant increase in efficiency. It has made the multi-anode rectifier obsolete. Since 1937, when Ignitron rectifiers became commercially available, in excess of 2,250,000 kilowatts capacity has been installed.

Applications in the central station field include generator excitation, frequency changing, d-c transmission, carrier current relaying and supervisory control, pilot-wire relaying, telemetering, automatic synchronization, recording instruments, and small isolated metropolitan d-c loads.

* Information supplied by Gordon F. Jones, Electronics Engineer, Westinghouse Electric and Manufacturing Company.

Welding Society to Meet in Chicago

The American Welding Society will hold its Twenty-fourth Annual Meeting at the Morrison Hotel, Chicago, the week of October 18. Sixty-five papers have been scheduled for presentation at several simultaneous sessions, in addition to symposiums.

Because of the important rôle played by welding in war production, the majority of the papers will deal with ship, aircraft and ordnance work, while others are devoted to research, repair and maintenance, training of welders, piping, cutting, railroad welding and general production. One session will be devoted to pressure vessels at which E. R. Fish, of the Hartford Steam Boiler Inspection and Insurance Company, will discuss "Adaptation of War Emergency Code Materials to Welded Pressure Vessels" and Dr. W. A. Pearl, of Whiting Corporation, will discuss "Welding of Dissimilar Metals."

Coal Stocks and Production

Production of bituminous coal continues a slow upward trend toward pre-strike levels while stocks in storage declined approximately $5^1/_2$ million tons during June. This drop was cushioned to some extent by a lower rate in consumption with the result that, measured by the current rate, the average number of days supply on hand dropped from 54 to 52.

The consumption of bituminous coal during June, as recently released by the Office of Solid Fuels Administration, was distributed as follows:

	Tons
Electric utilities	6,023,000
Byproduct coke ovens	7,178,000
Beehive coke ovens	672,000
Steel and rolling mills	824,000
Coal-gas retorts	126,000
Cement mills	473,000
Other industries	10,120,000
Railroads (Class I)	9,855,000
Retail deliveries	7,500,000
Total	42,771,000

Total production for the year, as of July 24, as 325,388,000 tons which was about 2 million tons in excess of that for the same period of 1942.

Stocks held by these industries as of July 1, totaled 74,028,000 tons and averaged, in terms of days supply:

	Days
Electric utilities	94
Byproduct coke ovens	30
Steel and rolling mills	35
Coal-gas retorts	84
Cement mills	41
Other industries	81
Railroads (Class I)	36
Retailers	27

The total production of anthracite for the year up to July 24 was 33,462,000 tons which represented a decrease of 1.1 per cent under that for the same period during 1942.

Joint Fuels Conference

The Annual Joint Fuels Conference of the Coal Division of the American Institute of Mining and Metallurgical Engineers and the Fuels Division of the American Society of Mechanical Engineers has been scheduled for October 28 and 29 at the William Penn Hotel, Pittsburgh. A general committee, representing the two societies and consisting of T. E. Purcell, Chairman, H. F. Hebley, L. E. F. Wahrenburg, A. W. Thorsen, T. J. Barry and H. P. Greenwald, is at work preparing plans for the meeting. The program will be announced shortly.

Obituary

George H. Gibson, well-known engineer and inventor, and President of the Geo. H. Gibson Advertising Company, died at Montclair, N. J., on July 28, following a brief illness. He was 67 years old.

An engineering graduate of the University of Michigan, Mr. Gibson's early experience was with the Westinghouse Company, following which he took up the field of technical journalism and advertising. He formed his advertising company in 1905 and his clients numbered many well-known manufacturers of power plant equipment. His publicity work was predicated on sound engineering knowledge and over the years he had contributed much to technical literature. Among his inventions were the Leeds & Northrup combustion control, the Cochrane chemical proportioner and generator and a number of patents on fans and pumps. He was a member of the A.S.M.E., the Navigators Club of New York and the Northport Yacht Club, the latter reflecting his hobby of yachting.

Surviving are his widow, Mrs. Anna J. Gibson, three sons and a daughter.

Conrad N. Lauer, past president of the A.S.M.E. and Chairman of the Board of the Philadelphia Gas Works Company died on August 2 at the age of 73. He became associated with that company in 1917 after fifteen years with the engineering firm of Dodge & Day, which later became Day & Zimmerman. In 1929 he established a trust fund to found the Hoover Medal which is awarded by the A.S.M.E. for outstanding engineering service.

this cable drag scraper . . .

. . . DIGS EITHER SIDE UP!

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In addition to complete dragline coal storage systems, Beaumont Birch manufactures and installs a full range of coal and ash handling equipment.

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WAR conditions demand that adequate stockpiles be created now. In answer to the need, Sauerman Power Drag Scrapers are being installed at numerous plants throughout the nation, in some cases to provide coal storage where none existed before; in others, to expand existing storage facilities at low cost.

Sauerman Equipment stores and reclaims safely, rapidly, cleanly for only a few cents per ton. Builds a homogeneous pile in compact layers—free of combustion hazards. Operates with a minimum of champing across pile and avoids dirt and dust of heavier equipment.

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Sauerman Advantages:

- Low-cost equipment
- One man operation
- Higher stockpiles
- Greater safety
- Upkeep simple
- Adjustable to any space

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Personals

John Sengstaken, formerly of The Air Preheater Corporation, has recently joined the Western Precipitation Corporation as Eastern Manager with headquarters at 405 Lexington Avenue, New York.

D. S. Wegg, formerly with the American Writing Paper Company at Holyoke, Mass., is now with Jackson & Moreland, Consulting Engineers, Boston.

J. E. Tobey has been reappointed Chairman of the Technical Advisory Board of Bituminous Coal Research, Inc.

Frederic I. Lackens, Advertising Manager of The Hays Corporation, has been elected President of the National Industrial Advertisers Association.

W. W. Foreman has been made Assistant General Superintendent of the Connecticut Light & Power Company. He formerly had general supervision of plant operation and construction.

Homer S. Burns, Assistant Vice-President and Superintendent of Power of the Freeport Sulphur Company is retiring on September 1 after thirty years service.

Your Bond Selling Responsibilities Double!

Starting September 9th, your Government will conduct the greatest drive for dollars from individuals in the history of the world—the 3rd War Loan.

This money, to finance the invasion phase of the war, must come in large part from individuals on payrolls.

Right here's where YOUR bond selling responsibilities DOUBLE!

For this extra money must be raised *in addition* to keeping the already established Pay Roll Allotment Plan steadily climbing. At the same time, every individual on Pay Roll Allotment must be urged to dig deep into his pocket to buy *extra* bonds, in order to play his full part in the 3rd War Loan.

Your now *doubled duties* call for these two steps:

1. If you are in charge of your Pay Roll Plan, check up on it at once—or see that whoever is in charge, does so. See that it is hitting on all cylinders—*and keep it climbing!* Sharply increased Pay Roll percentages are the best warranty of sufficient post war purchasing power to keep the nation's plants (*and yours*) busy.

2. In the 3rd War Loan, every individual on the Pay Roll Plan will be asked to put an *extra two weeks salary* into War Bonds—over and above his regular allotment. Appoint yourself as one of the salesmen—and see that this sales force has every opportunity to do a real selling job. The sale of these *extra* bonds cuts the inflationary gap and builds added post-war purchasing power.

Financing this war is a tremendous task—but 130,000,000 Americans are going to see it through 100%! This is their own best *individual* opportunity to share in winning the war. The more frequently and more intelligently this sales story is told, the better the average citizen can be made to understand the wisdom of turning every available loose dollar into the finest and safest investment in the world—United States War Bonds.

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BACK THE ATTACK *With War Bonds!*

This space is a contribution to victory today and sound business tomorrow by Combustion.

BOOKS

1—The Organization and Training of Industrial Fire Brigades

By Captain John C. Klinck

120 pages Size 6 × 9 Price $1.00

The training of industrial fire brigades was an important undertaking in time of peace, but now that we are at war, the protection of American industries and business property becomes an urgent necessity.

This manual has been prepared expressly for the use of fire department officers who are faced with the problem of organizing and training private fire brigades within industrial plants, storage warehouses and other large buildings. It shows how such a force can be organized and provides a thirty-hour course of training in the fundamentals of fire-fighting. The instruction contained in the text is amply supported by more than 150 drawings which admirably illustrate the theory of fire-fighting and the use of fire-fighting equipment.

2—Questions and Answers for Marine Engineers

Compiled by Captain H. C. Dinger, USN (Ret.)

Size $5^1/_8 \times 8^1/_8$

Paper covers Price $1.00 per book

During the past decade *Marine Engineering and Shipping Review* has published "Questions and Answers" as a means of imparting practical information regarding many boiler and engine-room problems. These have been collected and classified in a series of booklets, as follows:

Book I—Boilers
Book II—Engines
Book III—Auxiliaries
Book IV—Applications of Steam and Heat in Producing Power
Book V—Powering Fuel Economy, Propulsion, Propellers and Shafting
Book VI—Water Treatment, Corrosion and Safety Rules
Book VII—Diesel Engines, Electrical Equipment
Book VIII—Materials and Calculations, Handy Tables

The questions and answers have been grouped according to subjects and their subdivisions. In some instances somewhat similar questions are answered in a similar manner but modified to bring out information of interest or value. All volumes are completely indexed, and explanatory notes and dates have been added where clarification was considered necessary.

These books admirably fulfill the intention of the author in providing a helpful means of expanding the knowledge of the marine engineer. They can also be studied with profit by men preparing for license examinations.

3—A First Course in Mathematics

By Edward Baker

295 pages Size 6 × 9 Price $3.00

This book follows the traditional plan of proceeding from the less difficult to more difficult subjects and the study of analytic geometry is postponed to the latter part of the book. The increasing importance of vector concepts in pure and applied mathematics has prompted the author to place a greater degree of emphasis upon vector ideas than is customarily accorded in an elementary textbook, with the result that a simpler and more direct approach is possible to certain topics.

A First Course in Mathematics contains 22 cogently written and adequately illustrated chapters. The topics contained in each chapter are subdivided into pertinent sections, most of which are followed by numerous exercises relating to the subject discussed.

4—Heating, Ventilating, Air Conditioning Guide—1943

1250 Pages Size $6^1/_4 \times 9^1/_4$ Price $5.00

The 21st edition of the *Guide* issued by the American Society of Heating and Ventilating Engineers contains 48 chapters of technical data and general information pertaining to all phases of heating, cooling, ventilating and air conditioning, and related phases of refrigeration.

An important part of the *Guide* is the Revised Catalog Section in which much useful data on equipment have been supplied by manufacturers.

5—Economy Loading of Power Plants and Electric Systems

By Max J. Steinberg and Theodore H. Smith

203 pages Size $5^3/_4 \times 9$ Price $3.50

The material presented in this book has been developed to meet the requirements of load dispatchers, system operators and operators of generating station equipment to whom the allocation of load to power plants and to the equipment within them is an ever-present problem of producing electric energy at the lowest possible cost consistent with the obligation of maintaining continuity of service.

The book is divided into six comprehensive chapters dealing with Theoretical Background, Load Division in the Boiler Room, Load Division in the Turbine Room, Station Performance, System Load Division and Miscellaneous Applications. The text is supplemented with 41 tables, 94 charts and 4 photographic halftones showing the loading slide rule with various strip charts.

6—Ripper's Heat Engines

Revised by A. T. J. Mersey

337 pages Size $5 \times 7^1/_2$ Price $1.60

The continued popularity of this textbook is evidence that its broad scope and concise treatment satisfy the needs of a large number of students. This new American edition follows the most recent English edition by the omission of obsolete matter and by the inclusion of revisions and additions to bring the book into line with present practice.

The fundamental principles of heat and energy are discussed in the opening chapters and the main application of these principles to reciprocating steam engines in those that follow. Considerable attention is given to component parts, auxiliaries, boilers and the combustion of fuel, while the concluding chapters deal with steam turbines, and internal combustion engines. Numerous exercise problems are given at the end of the book.

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EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1943 Water Tube		1942 Water Tube		1943 Fire Tube		1942 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	11	64,169	197	1,590,796	18	22,854	52	59,476
Feb.	35	175,308	216	1,467,900	244	151,055	58	83,647
Mar.	32	149,983	268	1,487,505	17	25,043	60	62,679
Apr.	96	‡364,146	422	2,402,579	22	33,231	46	61,054
May	127	683,052	156	1,243,328	9	14,106	57	83,147
June	165	689,045	139	847,562	24	40,763	57	74,231
Jan.-June, incl.	466	2,125,783	1,398	9,039,670	334	287,052	330	424,234

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold in the period Jan. to June (incl.) 1943, 21,558,000 lb per hr; in 1942, 77,630,000 lb per hr.

Marine Boiler Sales

	1943 Water Tube		1942 Water Tube		1943 Scotch		1942 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	627	2,261,623	237	1,119,437	1	1,080	—	—
Feb.	31	102,404	70	347,324	—	—	—	—
Mar.	208	602,051	1,676	7,827,106	1	2,565	—	—
Apr.	19	85,244	236	848,986	2	5,130	1	161
May	1,028	5,032,948	364	1,473,354	3	6,401	2	868
June	895	4,241,507	255	876,146	1	2,565	—	—
Jan.-June, incl.	2,808	12,439,893	2,838	12,492,353	8	17,741	3	1,029

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to June (incl.) 1943, 108,507,000 lb per hr; in 1942, 95,122,000 lb per hr.

†Mechanical Stoker Sales

	1943 Water Tube		1942 Water Tube		1943 Fire Tube		1942 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	134	48,448	87	42,876	457	31,623	159	24,135
Feb.	104	34,858	131	55,001	575	83,673	185	26,889
Mar.	114	48,367	84	46,055	573	77,951	210	31,329
Apr.	99	33,781	102	49,061	433	64,172	313	39,877
May	96	39,640	125	44,069	414	57,889	206	33,566
June	113	60,550	123	48,267	366	48,970	296	49,760
Jan.-June, incl.	660	265,644	652	285,329	2,818	364,278	1,369	205,556

† Capacity over 300 lb of coal per hr.

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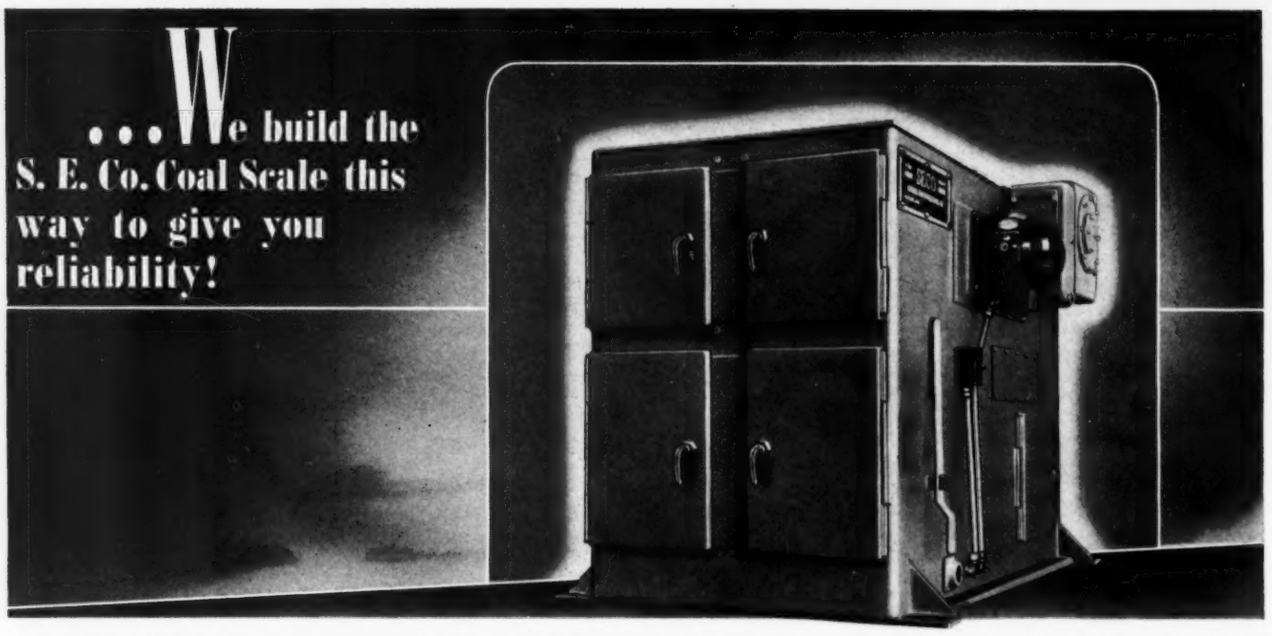

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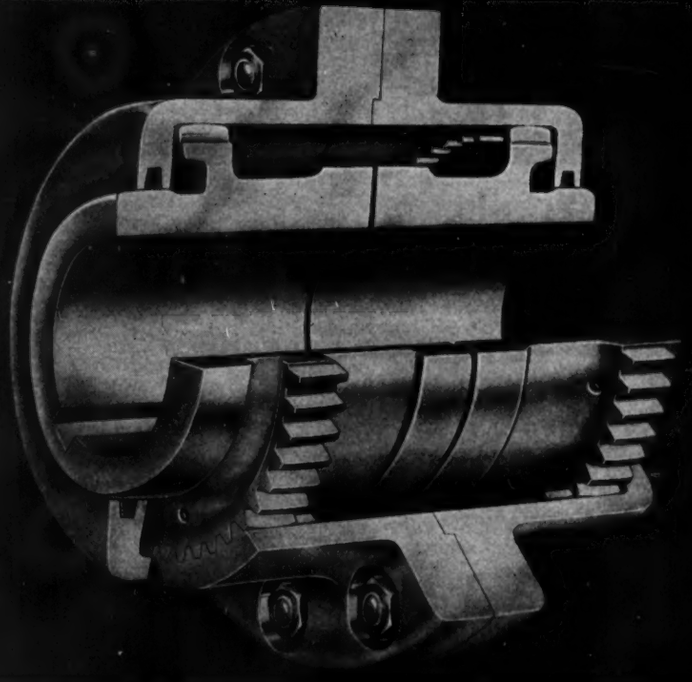

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NEW CATALOGS AND BULLETINS

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Arc-Welding Accessories

A new 36-page bulletin (GEA-2704C) issued by General Electric Company's Welding Division comprehensively describes all the standard and the many new G-E arc-welding accessories now available. Prominently featured in this well-illustrated publication is the full G-E line of chrome-leather, asbestos and flameproofed-duck protective clothing for both men and women operators. Other items illustrated and described are ventilated helmets and head protectors, observation shields, electrode holders and miscellaneous equipment such as slag chippers, electrode carriers and fillet-weld gages. Also listed are standard sets of welding accessories and renewal parts.

Boiler Meter

The Republic Flow Meters Company announces a new boiler meter which consists of an electric recording and integrating steam flow element combined with an oil-sealed bell type recording air flow meter. The operation of the meter with regard to steam flow from the boiler and the rate of air flow to the furnace is described and illustrated in a colorful 8-page bulletin (No. 420) just issued. This boiler meter uses a 12-in. record chart, and, should flue gas temperatures (or steam pressure) be required, a third pen may be added to the instrument.

Carbite Softeners

"Cochrane Carbite Softeners" is a new publication (4021) issued by Cochrane Corporation descriptive of its carbonaceous zeolite softeners. This bulletin describes the many uses and applications of the newly developed carbonaceous zeolite softeners, particularly as pertains to the treatment of boiler feedwater supplies. The bulletin describes the chemical reactions and general arrangement of the equipment, the results to be achieved and application to different water supplies, and other pertinent information that is of value to engineers considering water softener problems.

Gear Motors

G-E gear-motors are featured in a new 16-page, illustrated bulletin (GEA-1437D) recently issued by the General Electric Company. The new bulletin describes the many types of gear motors now furnished by General Electric, lists their advantages and indicates the various locations where their use is most desirable. The bulletin also contains descriptions of the mechanical features of these motors, the electrical characteristics of the polyphase motors which are integrally built into them and charts showing their horsepower-speed ratings.

Hot Spot Indicators and Quenchers

Coal Specialties Company has issued a 9-page bulletin (No. 100) entitled "Instructions for Using Hot Spot Indicators and Hot Spot Quenchers." This multigraphed bulletin describes the indicators and how to install them, tells how to replace the fusible links, and how to use the hot spot quenchers. These instructions are supplemented by an article on the storage of bituminous coal by A. T. Ward.

Lubricants and Core Oils

"90 Years of Industrial Pioneering" is the title of a 40-page booket issued by the Swan-Finch Oil Corporation on the occasion of its 90th anniversary. This tastefully produced booklet outlines the origin and growth of the Company and the historic part it has played in the development of lubricants and core oils which have accelerated the rapid advance of mechanization in all branches of industry and agriculture.

Multiple-Point Recorder Charts

Leeds & Northrup Company has issued a 6-page folder (N-163-2) featuring Split Charts which are divided into two or even three vertical sections. Among the numerous pictures and full color reproductions of actual chart records is a full size 24-hr tear-off chart section. The folder also describes a tear-off device with which new Micromax recorders (or those built since June 1936)—single or multiple-point—can be equipped.

Pump Test Code Revised

Hydraulic Institute, the national trade association of pump manufacturers, announces complete revision of the Test Code Section of its Standards. This Test Code Section, first published in 1936, contains specific recommendations for the testing of centrifugal and rotary pumps, both for acceptance tests in the field, and in the plant of the pump manufacturer. The Code contains the limiting conditions for all methods of quantitative determination of capacity, head and power input, whereby the accuracy for an acceptance test can be obtained.

Copies may be secured from Hydraulic Institute, 90 West Street, New York 6, N. Y., at 50 cents per copy, payable in advance.

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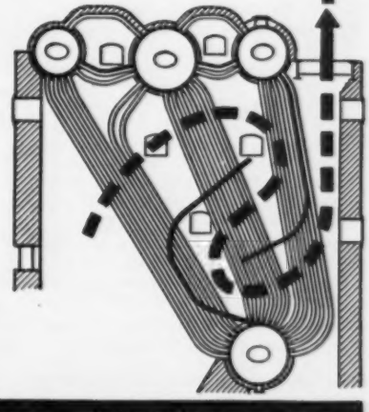

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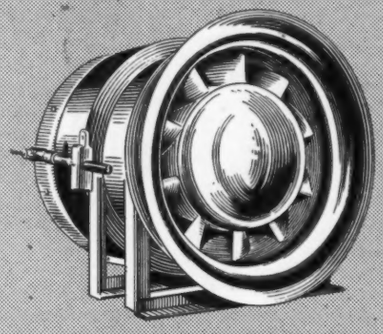

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